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FOREWORD

This report presents findings of a study sponsored jointly by the National Aeronautics and Space Administration and the United States Air Force to determine the feasibility of designing and implementing a computerized human factors data handling system. The report was prepared by the American Institute for Research, Pittsburgh, Pennsylvania. It was prepared for the Behavioral Sciences Laboratory, Aerospace Medical Research Laboratories, Aerospace Medical Division, Wright-Patterson Air Force Base, Ohio. The study was conducted under Contract No. AF33(615)-1557 to Computer Concepts Incorporated of Silver Spring, Maryland, as the prime contractor. The period of performance by the American Institute for Research was 15 June 1964 to 15 February 1965. The principal investigator was Mr. L. D. Hannah.

The study was conducted in support of the project number 1710, "Training, Personnel, and Psychological Stress Aspects of Bioastronautics," and task number 171006, "Personnel, Training, and Manning Factors in the Conception and Design of Aerospace Systems." Dr. Gordon Eckstrand, Chief, Training Research Division, was the project scientist and Mr. Melvin T. Snyder, Chief, Personnel and Training Requirements Branch was the task scientist. Mr. Lawrence Reed of the Personnel and Training Research Branch served as the contract monitor.

The authors wish to acknowledge the help of the interviewees and respondents who supplied the basic information upon which this report is based. Since the information was given with the promise of maintaining anonymity they must remain nameless. We wish also to thank Mr. Lawrence Reed for his work in coordinating the project efforts and providing entrée to the various sites visited, and Dr. Eckstrand and Mr. Snyder who assisted in the review of the manuscript.

This technical report has been reviewed and is approved.

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ABSTRACT

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On the basis of information gathered from generators and users of human factors task data by both interviews and questionnaires and by a review of relevant literature, human factors personnel and data were identified, the relations between them described, and recommendations for an automated human factors task data handling system proposed. Human factors personnel were clearly divisible into four hierarchically arranged groups: Program Level Managers, Personnel Subsystem Managers, Department Heads, and Nonmanagerial Personnel. In general, and for the populations described, managers or supervisors were the principal users and nonmanagerial personnel the principal generators of human factors data. A framework that permits classification of both formatted and unformatted data was proposed as responsive to the generally felt need by data generators and users for more orderly "book-keeping" in the human factors realm. Desirable characteristics of an automated human factors task data handling system were derived from the questionnaire responses. The responses also indicated that: (1) about 80% thought some use could be made of computers in their work, (2) retrieval time was important to at least 80%, (3) current modal data retrieval times range from 1 to 6 days, (4) about half of the respondents were dissatisfied with current data retrieval times, (5) retrieval times of less than 1 day would probably not be used more than twice a month by each respondent. Recommendations for implementing the system included steps necessary to design and apply it on a modest scale consonant with current system development.

Author

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SECTION I

INTRODUCTION

Problem

The size, complexity, and compressed developmental schedules of modern weapon and space systems have resulted in the generation of increasingly unwieldy amounts of human task data. Consequences of this unwieldy bulk of data include reliance on expertise when existing data are not known to exist or are inaccessible, inadvertent duplication of research efforts, and scattering of costly information. These problems could be at least partially alleviated by the development of an automated system for efficient storage, accurate processing, and rapid retrieval of human task data and related information. Prerequisite to the design of such a system are knowledge about the nature of the data to be handled, and of the generators and users of the data. It was to these general ends that the study was directed.

Purpose

The purpose of this research was to identify and define the important parameters for the development of an automated human factors data handling system by:

1. Identifying representative groups of technical and professional specialists who generate or use human factors task data.

2. Identifying representative types and methods of presentation and exchange of human factors task data generated and/or used during the phases of system design, development, test, and operation.

3. Relating the data identified with specialist groups and indicating (a) by whom and how the data are generated and used, and how the data are applicable to a specific phase of system design, development, testing, or operation; and (b) recommending alternative procedures.

4. Describing the impact of the data and the method of presentation of the data upon the system design, development, operation, and the related management decisions.

5. Describing present techniques and suggesting alternative techniques by which the language of human factors task data and information could be standardized or used consistently, and especially in consonance with operational and engineering terminology.

Scope

Although it may be argued that the generation and use of human task data is related to virtually all of the information resulting from aerospace development, the scope of this study was limited to classes of data that are commonly used to make design decisions affecting man's role in systems or to describe this role. Human factors task data and related man-machine information were for the purpose of the study defined as including the qualitative and quantitative task and performance data for operator and maintenance personnel. These task data emphasized the behavioral data of human engineering, human learning and training, and training equipment, and included for example: (1) the demands that the system, man, or the situation make upon one another (e.g., the working environment, time criticality, performance accuracy); (2) discrete task information such as expected or required task and skill parameters for fixed and/or variable task procedures; (3) the applications of skills within system mission segments and time base, where skills pertain to such functions as detecting and processing information, monitoring and communicating with or directing machines or humans, command or decision making, feedback and self-alignment or adjustment.

Although information currently available through such sources as Defense Documentation Center (DDC), Tufts Institute, and Documentation Incorporated was clearly relevant to the design and description of human tasks for space systems, it was beyond the scope of this study to incorporate all data in existing retrieval centers or to supplant the activities of such centers. Rather, it was felt that any system resulting from this study should be compatible with outputs and input requirements of existing human factors data systems.

Overview

The primary concern of this research was with the description of a human factors data base and its potential uses. The principal parts of the report describe:

1. The approach to gathering and analyzing information about the kinds of human task data involved in aerospace system development and the ways in which such data are generated, processed, stored, retrieved, disseminated, and used.

2. Results from surveying human factors literature, from information and opinions expressed by system development personnel who were interviewed, and from questionnaires sent to human factors personnel.

3. An idealized summary of the network for generating, handling, and using human task data throughout system development.

4. Categories of human task and related data which an automated system must be capable of handling, and which may be useful in the initial formulation of a language for such a system.

5. Current uses of computers and recommendations of characteristics desirable in an automated system for handling human factors data.

6. Specific recommendations for the implementation of a computerized data handling system in the immediate future.

SECTION II

APPROACH

Data Gathering

A literature review, interviews, and questionnaires were used to gather data.

The literature review was conducted to determine the range and kind of data considered to be in the human factors domain, the ways in which such data are customarily classified, the uses made of the data, and current methods of handling the data. Particular attention was directed toward documents which related data and data handling methods to the development of space and weapons systems.

A more detailed description of the literature review may be found in Appendix I.

Interviews were held with persons engaged in activities primarily concerned with the use or generation of human factors data. The purpose of the interviews was to elicit information useful in defining the range of the basic human factors data pool, the exact nature of data used in system development, the uses made of data, and the ways in which data are integrated and eventually become a part of the operating system.

The interviews were held with 73 persons in 12 offices engaged in system design, development, and operation. A summary of the phases of development and types of systems selected for study is presented in Table I.

The persons who were interviewed often volunteered information about projects with which they had previously been associated. Information about seven additional systems was obtained in this way. A summary of the types of these seven systems is presented in Table II.

A detailed description of the interview procedure is attached as Appendix II.

Questionnaires were distributed to 142 human factors data generators and users involved in various aspects of system design, development, and operation. Their names were obtained from the Directory of the Human Factors Society and from published manufacturers' organization charts. The selection criteria for the systems with which the prospective respondents were associated were identical to those used for the interviews (see Appendix II). Whereas the interviews had made it possible to follow leads as they were

Table I

Phases of Development and Types of Systems Selected for Inclusion in the Study

System	Associated Contractor or Agency	Phase	Type: Air Force	National Aeronautics & Space Administration	Manned	Unmanned	Weapon	Research	Aircraft	Missile
A	6	Late Category II Test, Acquisition	X		X		X			
B	7	Mock up, Development, Acquisition		X	X					
C	2, 3	Pre-production, Acquisition	X		X		X			
D	1	Late Production, Operational	X		X		X			
E	9	Conceptual	X		X			X		
F	5	Definition		X	X			X		
G	3	Definition			X			X		
H	2, 4	Category III, Test Operational	X			X	X			
I	8	Design		X		X		X		

Table II

Systems with which Interviewees had been Previously Associated

		Type							
System	Associated Contractor or Agency	Air Force	National Aeronautics & Space Administration	Manned	Unmanned	Weapon	Research	Aircraft	Missile
J	6	X		X			X		
K	7		X	X			X		
L	3	X		X		X			
M	2		X	X			X		
N	5	X		X		X			
O	5		X	X			X		
P	4	X			X	X			

uncovered during the investigation, the questionnaires provided quantifiable information which would have been difficult to obtain in an interview situation. The use of questionnaires also made possible extension of the number of individuals contacted as well as the kinds of activities and systems encompassed by the survey.

A sample questionnaire is attached as Appendix III.

Analysis

Analysis was accomplished in four steps. Information from literature, interviews, and questionnaires was organized and summarized within inductively derived categories. Results from this first order of analysis were abstracted and organized into a description of the system development network for handling human task and related data. First order and network analyses were used in deriving categories of human task data which seem most cogent for an automatic handling system. All of these were considered in summary. Finally, desired characteristics of an automated human factors data handling system were derived; recommendations were made for implementing these characteristics.

Further descriptions of the data analyses are presented in Appendix IV.

SECTION III

HUMAN FACTORS PERSONNEL AND DATA

Information bearing upon human factors personnel and data was organized into sections that were responsive to one of four major questions concerning human factors in system development: who are the users and generators of human factors data?; what is the nature of human factors data?; what are the relationships which exist between human factors personnel, data, and systems?; and, what is the impact of human factors data in system development?

The generators, users, and types of human factors data, and the impact of human factors considerations are intimately related by virtue of their integration in system design, development, and operation. The presentation which follows, therefore, proceeds through brief separate considerations of these factors to detailed descriptions of the relations between them.

Human Factors Personnel

The ultimate users of human factors data are collective groups such as Air Force Commands and National Aeronautics and Space Administration (NASA) Headquarters or various NASA centers that "buy" systems and the individuals who operate, maintain, and support them. Due to the Interdependence of all facets of design and operation, however, separation of human factors aspects of a system from all the other aspects was impossible at this management level. At all other levels the individuals responsible for solving problems that arise as the result of interactions between people and machines can be identified.

Interviewees

Of the 73 persons interviewed, four of the six Personnel Subsystem Managers had doctor of philosophy degrees in psychology. The remaining two Personnel Subsystem Managers were a design engineer, and a retired Air Force pilot with human factors and engineering experience. No background information was obtained for two Contract Managers.

Five of the 17 Department Heads were doctors in philosophy in psychology, and one was a doctor of philosophy in English. The remaining group of 11 Department Heads was comprised of four training specialists, four human factors specialists, and three engineers.

Of the 48 non-managerial personnel, seven could be positively identified as human factors specialists and one was an engineer. The non-managerial personnel were characterized by heterogeneity of formal educational background (with a slight preponderance of engineering training) and varying degrees of on-the-job human factors experience.

Respondents to the Questionnaires

In order to assess differentially the interactions between human factors personnel and data, the respondents to the questionnaire were divided into "Personnel Groups." The results of this classification are summarized in Table III. Here it can be seen that, based on the principal functions performed by the respondents, four such groups were identified.

Lists of specific job titles included in each Personnel Group are attached as Appendix VII.

Analysis of the questionnaires also provided additional information about generators and users of human factors data. Items 2 through 5 on the questionnaires were designed to yield data related to the identification of generators and users of human factors data. Items 2 and 3--position and closest working associates--served to locate the respondents in the system hierarchy, while items 4 and 5--journals most frequently read, and professional association memberships--served to identify the backgrounds and interests of the respondents. It should be noted that in the item which concerned journals most frequently read the respondents were enjoined not to indicate data sources. The intent was to examine the respondents as professional individuals rather than as holders of specific jobs. The analyses of items 6 through 8 served to relate classes of human factors personnel ("Personnel Groups") to sources and forms of processing of data, as well as to forms of outputs.

The professional journals and technical publications most frequently read by the respondents were sorted into either of seven categories of psychological periodicals, nine categories of non-psychological periodicals, or five categories of aperiodically published technical documents. The results of this sorting are presented in Table IV which shows that the aeronautical, general psychological periodicals, and applied psychological periodicals accounted for 48 per cent of the total responses to this item. If technical research reports, general scientific periodicals, and bio-medical periodicals are added to these three categories, about 79 per cent of the response distribution will have been included. The remaining 21 per cent of the responses were widely distributed among the other categories.

Since human factors efforts are comprised of scientific endeavors in the general domain of psychology and, since all of the respondents had at one time been involved in aerospace efforts, these results are as would have been predicted: the reading habits of the respondents were reflective of their fields of specialty.

Table III

Principal Functions Performed by the Respondents to the Questionnaires

Personnel Group	N	Function
Program Level Managers	9	Direct the functions of offices within a command, division, system program office, or a test center.
Personnel Subsystem Managers	16	Coordinate human factors research and related activities in system development.
Department Heads	19	Direct a department, division, or other group within the personnel subsystem of a research and development establishment.
Non-managerial Personnel	23	Conduct research on projects assigned to the personnel subsystem of a research and development establishment.
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*This figure represents a return of 47 per cent of 142 questionnaires.

Table IV

Frequencies of Reading Professional Journals and Technical Publications by Personnel Groups

	Response Category / Personnel Group	Program Level Managers X	Program Level Managers %	Personnel Subsystem Managers X	Personnel Subsystem Managers %	Department Heads X	Department Heads %	Non-managerial Personnel X	Non-managerial Personnel %	Total X	Total %
Periodicals	Applied Psychology	1	2	16	18	19	21	18	16	54	16
Periodicals	General Psychology	1	2	16	18	15	16	10	9	42	12
Periodicals	Miscellaneous Psychology	1	2	3	3			1	1	5	1
Periodicals	Personnel Psychology					2	2			2	1
Periodicals	Psychometry			1	1	1	1			2	1
Periodicals	Aviation Psychology							1	1	1	0
Periodicals	Mathematical Psychology			1	1					1	0
Periodicals	Total Psychology	3	7	37	42	37	41	30	26	107	31
Periodicals	Aeronautical	18	39	7	8	16	18	28	24	69	20
Periodicals	General Science	11	24	11	12	8	9	7	6	37	11
Periodicals	Biomedical	2	4	11	12	2	2	14	12	29	9
Periodicals	Electronic			2	2	6	7	3	3	11	3
Periodicals	Engineering			1	1	7	8	3	3	11	3
Periodicals	Computer			2	2	5	6	2	2	9	3
Periodicals	Education	3	6			2	2	1	1	6	2
Periodicals	Business	1	2			1	1	4	3	6	2
Periodicals	Miscellaneous Non-psychology			1	1	2	2	2	2	5	1
Periodicals	Total Non-psychology	35	76	35	39	49	54	64	56	183	54
Technical Documents	Technical Research Reports	4	9	14	16	5	6	15	13	38	11
Technical Documents	Data Abstracts and Bibliographies			2	2			5	4	7	2
Technical Documents	Internal Communication	2	4	1	1					3	1
Technical Documents	Weapon System Research Reports	2	4							2	1
Technical Documents	Textbooks							1	0	1	0
	Total Technical Documents	8	17	17	19	5	6	21	18	51	15
	Total Responses	46		89		91		115		341	

A comparison of the types of material most frequently read by Program Level Managers to those of the other three Personnel Groups revealed an interesting difference: only three of the 107 responses in the psychological periodicals categories were given by the Program Level Managers, who tended to favor aeronautical and general scientific literature somewhat more than did the other three Personnel Groups. This is undoubtedly related to the fact that, whereas the three hierarchically lower groups were heavily populated with civilian, professional, psychologists and engineers who worked for private organizations, the hierarchically higher groups were composed exclusively of managerial and professional personnel who were employed by the Air Force or NASA.

The response distribution of the Personnel Subsystem Managers is also sufficiently different from that of the other Personnel Groups to warrant special mention. Aeronautical periodicals, much read by the other three groups, were relatively little read by Personnel Subsystem Managers whose frequencies of listing technical research reports, general scientific periodicals, and biomedical periodicals, nearly equaled those of listing general and applied psychological periodicals.

In Table V is presented a summary of the types of professional organizations to which the respondents belonged. As would be expected, the response distribution to this item paralleled in many respects that of the periodicals and technical publications: membership in psychological organizations accounted for 42 per cent of the total organizational membership and appeared in the first ranked position for all Personnel Groups. Second by rather wide margins were aeronautical, general scientific, and electronic organizations, which accounted for another 33 per cent of the responses. Membership in biomedical organizations was minor and in the remaining organizations negligible. Program Level Managers listed membership in aeronautical organizations proportionally more than did the other three groups. This difference, like the similar one noted with regard to the most frequently read publications, is probably occupationally related.

The relatively high frequency of membership of Personnel Subsystem Managers and Department Heads in electronic and electrical organizations indicates that these groups were probably more heavily populated with personnel who had had engineering training and experience than were the other two groups.

Human Factors Task Data

The most relevant government document (1) defines data as that collection of forms, drawings, and publications, the generation and subsequent distribution of which is essential to the development and operation of a system and which is contractually required by the procuring activity. Human factors data are further defined, at least implicitly, as those aspects of system development identified in regulations and

Table V

Frequency of Membership in Professional Organizations

Response Category \ Personnel Group	Program Level Managers		Personnel Subsystem Managers		Department Heads		Non-managerial Personnel		Total	
	X	%	X	%	X	%	X	%	X	%
Psychological	7	30	35	45	30	46	23	39	95	42
General Science	3	13	14	18	3	5	8	14	28	12
Aeronautical	6	26	7	9	6	9	5	9	24	11
Electronic & Electric	2	9	9	12	8	12	4	7	23	10
Biomedical	2	9	6	8	2	3	4	7	14	6
Educational	2	9	2	3	3	5	2	3	9	4
Mechanical	1	4	2	3	2	3	4	7	9	4
Industrial			1	1	3	5	4	7	8	4
Computer					5	8	2	3	7	3
Astronomical			1	1	1	2	1	2	3	1
Literature and Composition							2	3	2	1
Military					1	2			1	0
Ordnance					1	2			1	0
Sociological			1	1					1	0
Total Responses	23		78		65		59		225	

manuals as the "personnel subsystem." The personnel subsystem, in turn, is defined in terms of personnel subsystem elements. Current regulations and manuals (2, 3, and 1) are inconsistent in the presentation of the number and the proposed content of the elements.

Regardless of the number of personnel subsystem elements which are specified for a specific system, the data generating activities for all of them are generally grouped into no more than four organizationally independent entities at a contractor's plant. Although these groups are identified by a variety of names, they all deal with areas related to human engineering/life sciences, training, and personnel. A section identified as having the function of developing task analyses usually exists but is usually associated with the engineering or maintainability department or directly with the human engineering/life sciences department. These groups are usually given the responsibility for developing the entire personnel subsystem as defined by the contractual obligation of the contractor.

The data content of the products of personnel subsystem elements is described generally and in detail in the relevant government manuals and specifications previously mentioned. Analysis of the content of these reveals that the data center around the description of the behavior of the human and the implications of behavior for design of equipment, comfort and safety of the human, and acquiring and training the personnel necessary to accomplish the described behaviors.

An important part of all the specified elements includes the ancillary data required to set performance standards, criteria, and measurement techniques to test the relevance of the data developed, the adequacy of the data to support the system, and efficiency of the operation of the personnel subsystem when the system becomes operational. For efficiency in reporting test results these data are usually collated and defined as the personnel subsystem test and evaluation element.

Technical publications are specified as a personnel subsystem element by all relevant manuals and regulations, primarily because of the dependence of their generation on human factors data. Neither the contractors nor technical publication writers, however, consider the effort to be a primary human factors one. This fact, however, does not preclude inclusion of technical publications requirements for human factors data in a study of the data base.

The data base and its relation to these elements are further described in following sections which discuss the human factors network and data classification.

Relations between Personnel and Data

It became obvious early in the course of the interviews that joint consideration of position or rank in organizational hierarchies and the types of data generated and used would serve better to differentiate generators and users than would educational or experiential factors. Non-managerial human factors personnel reported that they use as their primary data sources handbooks (4 and 5), and raw data either from technical publications or their own experiments and task analyses. These data may be combined with or used to supplement system-specific data, engineering drawings, and experimental results for the solution of system-related problems. These results are in turn used by the Department Heads in making design recommendations. Department Heads reported that such documents as the Handbook of Instructions for Aerospace Personnel Subsystem Designers (HIAPSD) and Systems Management Series are also used as primary data sources.

Personnel Subsystem Managers use directives, specifications, and the products of their subordinates' efforts in the preparation of reports and other documents which then may become data for application to subsequently developed systems. It can readily be seen then, while the activities of those interviewees who were relatively low in the organizational hierarchies involved both the generation and use of human factors data, the activities of organizational managers and supervisors were virtually exclusive of human factors data generation; i.e., managers and supervisors are principally users of human factors data. An analogous group--one composed of personnel who generated but did not use human factors data--was not discovered. It appeared also that a decreasing proportion of human factors data generators was accompanied by an increasing proportion of users as systems proceeded from the conceptual to the operational phase.

A summary of the types of data sources and inputs used by the respondents is presented in Table VI. While not customarily regarded by procuring activities as data sources, military specifications were reported by all Personnel Groups as comprising their most important data source or input. Technical research reports, handbooks, and weapon system research reports accounted for 51 per cent of the responses to this item.

Program Level Managers indicated relatively less reliance on handbooks and more reliance on weapon system research reports and data than did the other three Personnel Groups. This is probably explicable on the basis of the research monitoring functions, including the frequent review of research reports, performed by Program Level Managers.

The forms of processing of information which were used in generating new personnel subsystem products were sorted into 14 Response Categories.

Table VI

Principal Data Sources

Response Category \ Personnel Group	Program Level Managers		Personnel Subsystem Managers		Department Heads		Non-managerial Personnel		Total	
	X	%	X	%	X	%	X	%	X	%
Military Specifications	13	33	41	32	41	27	40	26	135	28
Technical Research Reports	11	28	15	12	38	25	41	26	105	22
Handbooks	2	5	29	23	21	14	26	17	78	16
Weapon System Research Reports and Data	8	21	13	10	22	14	15	10	58	12
Textbooks	1	3	13	10	5	3	10	6	29	6
Data Abstracts and Bibliographies	1	3	8	6	9	6	7	5	25	5
Internal Communication	2	5	4	3	9	6	10	6	25	5
Procurement Specifications	1	3	3	2	4	3	2	1	10	2
Private Communications					5	3	5	3	10	2
Other (Psychological Journals)			1	1					1	0
Total Responses	39		127		154		156		476	

The results of this sorting are presented in Table VII where it can be seen that 31 per cent of the responses to this item were related to task analysis and engineering, and that another 32 per cent of the responses related to human engineering and procurement specifications.

A between-Personnel Group comparison of the Response Categories ranked first indicated that there exists a rather clear-cut division of labor within Air Force and NASA systems: the Non-managerial Personnel are principally involved in task analyses, Department Heads in engineering, and Subsystem Managers in human engineering. Although 25 per cent of the responses of Program Level Managers related to experimental studies, these all referred to the review of the results, rather than the conduct, of research.

Response Categories identical to those used for sorting the responses to the item which dealt with forms of data processing were used to sort the respondents' contributions ("principal outputs") to weapon system development. The principal outputs of the respondents are presented in Table VIII. Here it can be seen that, of all the responses to this question, 42 per cent were related to human engineering or task analysis, and 26 per cent to management, training, and testing.

The responses to the questionnaire item regarding forms of data processing indicated distinct differences between Personnel Groups in the ways in which they generated and used data. The respondents in each Personnel Group, however, indicated that about 24 per cent of their outputs were related to human engineering. The second largest portion (18 per cent) of the responses to this item related to task analyses.

Impact of Human Factors Considerations upon Management Decisions, Design, Development, and Operation

An objective evaluation of the impact of human factors data upon system design, development, operation, and related managerial decisions would require that these factors be treated as dependent variables upon which the effects of the inclusion, as well as the exclusion, of human factors data could be observed. Since such an experiment is obviously impossible, less direct alternative methods were used for assessing the degree to which current weapon and aerospace systems depend upon human factors data. The use of any method for observing these effects, however, requires prior consideration of the conditions which affect the inclusion or exclusion in systems of human factors considerations.

It was difficult to determine whether the considerations which governed the extent to which human factors were formally viewed as a part of system design and planning, and consequently the demands for human factors task data, were fortuitous, the result of careful planning and an obvious requirement or need, or some combination of the two.

Table VII

Forms of Data Processing

Response Category \ Personnel Group	Program Level Managers		Personnel Subsystem Managers		Department Heads		Non-managerial Personnel		Total	
	X	%	X	%	X	%	X	%	X	%
Task Analysis	4	17	8	10	10	11	24	27	46	16
Engineering	2	8	9	12	19	20	13	15	43	15
Human Engineering	1	4	14	18	9	10	8	9	32	11
Procurement Specifications	2	8	6	8	7	8	15	17	30	11
Experimental Studies	6	25	7	9	10	11	7	8	30	11
Testing			8	10	12	13	2	2	22	8
Function Analysis	3	13	2	3	7	8	3	3	15	5
Training	3	13	8	10			2	2	13	5
Manning			8	10	2	2	2	2	12	4
Mission Analysis	1	4	4	5	6	7			11	4
Maintainability			1	1	3	3	4	5	8	3
Reliability			2	3	3	3	2	2	7	3
Technical Publications	2	8			2	2	3	3	7	3
Personal Communication					3	3	3	3	6	2
Total Responses	24		77		93		88		282	

Table VIII

Principal Outputs

Response Category \ Personnel Group	Program Level Managers X	Program Level Managers %	Personnel Subsystem Managers X	Personnel Subsystem Managers %	Department Heads X	Department Heads %	Non-managerial Personnel X	Non-managerial Personnel %	Total X	Total %
Human Engineering	6	21	38	23	26	23	31	28	101	24
Task Analyses	2	7	36	21	15	13	23	21	76	18
System Management	4	14	24	14	10	9	8	7	46	11
Training	7	25	14	8	10	9	10	9	41	10
Testing	2	7	5	3	16	14	8	7	31	7
Experimental Studies	2	7	12	7	5	4	3	3	22	5
Function Analyses			11	7	7	6	4	4	22	5
Maintainability			7	4	9	8	4	4	20	5
Manning	2	7	6	4	4	4	7	6	19	5
Procurement Specifications	3	11	8	5			1	1	12	3
Technical Manuals			3	2	4	4	3	3	10	2
Mission Analysis			2	1	6	5	1	1	9	2
Engineering			1	1			5	5	6	1
Reliability			1	1	1	1	4	4	6	1
Total Responses	28		168		113		112		421	

The data gathered during the interviews, however, left little doubt that the following factors were the principal determinants of the extent of human factors considerations in the system which were examined:

1. Historical development of departmental functions in a plant. The development of large advanced systems was usually achieved by large organizations in cooperation with government agencies. It was with less frequency that advanced systems were developed within or separate from government agencies. In the early days of system development and when the necessity for the consideration of human factors was initially realized, specific functions were assigned to already existing sections or departments. Since such considerations had to be made in many different areas, the result was the growth of several human factors sections within the same plant, although each may have had different missions and, therefore, different data requirements. This type of development was seen as characteristic of the older manufacturers' (e.g., Contractor 2) organizations. For example, World War II aircraft weapon systems required that contractors place technical representatives in the field in order to accommodate maintenance training, troubleshooting, and modification implementation. Greatly improved training and human engineering departments grew out of this need.

2. Calendar time at the beginning of system development. Since the concepts of system planning and human factors are relatively recent developments both in the military departments and their suppliers, the rules and procedures which govern operations are constantly being revised. At the time of the inception of System D, for example, no formal personnel subsystem requirements existed. These were initially set forth in (2) at about the time of the inception of System C, and revised at least once before System C became operational. Such revisions required corresponding alterations in the operating plans for System C. Frequent revisions also serve to augment the interpretive latitude permitted by many existing regulations and specifications. In light of these considerations the resultant differences between contractors in emphasis of human factors considerations are not surprising. Whereas Contractors 4, 5, and 2 had elaborate computer systems for handling human factors data, Contractors 1 and 9 were little concerned with human factors considerations.

3. Time pressures during system development. When systems are developed within the time constraints imposed by "crash" programs, it becomes impossible to wait for what is considered the normal or usual sequence of events. The result, as observed in System C, was that system development took place on all fronts simultaneously. While it is explicitly stated (1) that such an approach is often the most desirable one, concurrency of effort was sometimes seen as working at odds with optimal system development, with increased, rather than decreased, duplication of effort as the result. Representatives from Contractor 4

attributed this primarily to the parallel development of problems which would have better been solved sequentially, thus making controlled data flow difficult.

The continual increase in the complexity of human performance requirements in weapon systems has placed many new requirements upon man in the system. Realizing this, many system planners (e.g., Contractors 4, 5, and 2) now emphasize heavily the requirements for human factors task data. In addition system planners and designers are recognizing the efficacy of requiring task data at an early point in weapon system development, and it appears that the temporal constraints imposed by crash programs have become an integral part of the usual operational mode. Heavy financial losses to Contractor 1 occurred as the direct result of inadequate human factors considerations in the development of System D.

4. Contractual requirements. When contracts are let, conflicting demands for available funds may determine the extent of human factors considerations for a system. Such was the case with Contractors 1 and 9, whose considerations of human factors were limited to those aspects without which the system could not operate. It was also discovered that in System E funds had been so drastically cut that development was proceeding on a very limited basis, and only the bare essentials were being accomplished. The trend, however, is toward systematically providing for the inclusion of human factors considerations in system development.

5. Kind of system. The requirements for data used in the development of ground based communications networks were clearly different from those used in a manned spaceflight system. These, however, were seen as differences in emphasis rather than in types of data. The degrees of emphasis on reliability and operability, for example, were greater for manned than for unmanned systems; in unmanned systems more emphasis was accorded maintainability.

6. Phase of system development. There occurs a shift in both the kind of data used and the degree of detail required in the progression from the conceptual to the operational phase of a system. During the early phases of system development, when hardware design was not yet firm, broad and general types of task analyses were used to make preliminary manning and training predictions. Later, increased knowledge of hardware details made possible more detailed task analyses for use in the preparation of technical orders and training manuals.

7. Personnel characteristics. The extent and the manner in which human factors were considered in the observed systems depended to a greater extent than was originally believed upon the personalities and idiosyncratic operational styles of the individuals responsible for such considerations. For example, the opinion was expressed by representatives of Contractors 2, 3, and 5, since "dynamic" human factors specialists are

well able to present a case for their data, their inputs were more often implemented than were those of the less "dynamic" ones.

A description of the impact of human factors data upon management decisions and the design, development, and operation of systems requires the joint consideration of all four of these factors, since an effect on any one will ultimately produce effects upon the others. For example, the design of systems depends ultimately upon management decisions, and operation serves either to confirm or infirm design and development decisions.

The majority of the comments made by the interviewees with regard to the impact of human factors considerations may be divided into two classes: those which for various reasons reflected a tendency to de-emphasize the importance of the role of human factors in the design, development and operation of systems; and those which expressed satisfaction with having included human factors considerations early in system design. There were no comments expressing dissatisfaction with early human factors considerations.

<u>Other Comments Regarding the Impact of Human Factors Considerations</u>.

Some comments were directly related to the impact of human factors data upon system design. Representatives from a government agency which had no separate human factors section or department identifiable as such, expressed satisfaction with human factors decisions made by their design engineers. The philosophy seemed to be that a good designer, a good operations analyst, a good technical writer, or a good training specialist would by definition be a good human factors specialist who would not ignore important human factors considerations relevant to the accomplishment of his mission. None of the persons contacted at this installation minimized the importance of human factors considerations; indeed, they were acutely ware of them. Their indications of the need for data and data sources which were used were similar to those indicated by other agencies and all contractors.

The comments of representatives of Contractors 2 and 3 were among those which reflected satisfaction with human factors considerations early in the system design. Regarding the design of System C,

> Early determination of requirements and the use of computers in handling task analysis and maintainability analysis data has made possible changes in the design which quite likely could not have been made without the response capability [we] have in [our] data handling system.

and

> The QQPRI and maintainability analyses are being completed [with the aid of computers] in time to be of value in the design phases of development.

Regarding the design of System F, representatives of Contractor 5 stated that,

> The importance of specifying requirements for human factors, especially task and function analysis by human factors specialists, early in development contracts becomes apparent here because of incidents following both inclusion and exclusion of such requirements.

A comment which tended to de-emphasize the importance of human factors considerations was made by representatives of Contractor 9:

> Very little has been done in the way of human factors. The RFP did not contain specific human factors requirements from the Air Force; therefore, arbitrary decisions had to be made in the proposed design of the system.

Other comments made by representatives of Contractor 9, however, reflected the efficacy of early human factors considerations:

> A study was initiated after several . . . crashes were traced to pilot having difficulty recovering from roll. The final design incorporated more roll-up horizons and changed lettering to white on black.
>
> Some functional and task analyses are completed before there are preliminary drawings to work from. This makes it possible to influence design before any tooling even has taken place. The feeling among human factors engineers at [Contractor 9] is that this is not just the best time for consideration of human factors, it is the only time.
>
> Without the specifications for the human in the system it is a difficult job to design the hardware and it is difficult to evaluate the effect of the design on the human.
>
> The beneficial result of the study in the design of the system was a considerable weight savings in the cockpit. The computer was used only to process the data--results of psychological tests taken as measures of performance decrement.

Regarding the nature of human factors research as performed in the design of System E, it was found that, "While the experiment may not be strictly controlled it often at least shows that the design as proposed does not conflict with human performance."

Another indication of the impact of human factors considerations upon management decisions was obtained in comments which reflected the importance to contractors and procuring activities of retaining currently generated human factors data for application to future system design:

The studies done for [System A] by the Human Engineering Lab. were all reported in quarterly progress reports to SPO whether information generated subsequently was reflected in actual system development or not (Contractor 6).

Although there are now no formal formats for reporting, study results will be written as specific reports on specific studies (Government Agency 3).

The contract requirement for complete system function analysis and experience gained on [System P] has made possible use of the Basic Concurrency Concepts in development of [System H] (Contractor 4).

The . . . test and evaluation data, being collected in the field on [System P] ever since the Category II stage and continuing into the operational phase, is used continuously to update [System H] (Contractor 4).

As much information as possible is needed from previous manned flights (Government Agency 3).

[Government Agency 3] did a survey of simulator capabilities in the U. S. in order to be realistic in preparing requirements for Phase "0" study contracts.

The prime purpose of the [System G] experiments will be to acquire and store information for use by designers of future systems (Government Agency 3).

Another indication of the impact of human factors efforts on system development was that all contractors visited had some permanent provision in their corporate organizations for, and supported as a matter of company policy, a human factors office or section. This was true even at installations where human factors efforts, identified by regulations and specifications as a personnel subsystem, were not a direct contractual obligation.

The amounts of personnel and money allocated by procuring agencies and by contractors for activities which were either identifiable as human factors activities or which depended on human factors data served as another index of their impact on system design, development, and operation. Although it was impossible to obtain precise estimates of these amounts, the interviewees who did choose to estimate costs indicated as minimal figures in the tens of millions of dollars. They indicated further that this was true even if one considered only the direct costs of human engineering in design for operability and maintenance, and the development of the relevant task analyses.

The preparation of technical publications depends heavily on what has been identified as task data or task related data. Representatives of Contractors 2 and 4 indicated that their technical publications sections employed more personnel and were more costly to operate than many of the major commercial publishing houses. Since regulations require more than one thousand separate published documents per system, this is not surprising.

Another indication of the impact of human factors considerations was obtained from representatives of Contractor 5. There had, at the time of the interview, been no contract let for System F, which was in the conceptual phase. Seven to eight per cent of the employees were hired by the contractor as "engineering psychologists," and were permanent staff members of the Human Engineering/Life Science (HE/LS) section of the plant. Further, since the pay of these personnel generally exceeded the average for the weapon system employees, human factors personnel were receiving about 10 per cent of the total budgetary allocation for wages.

Finally, an indication of the impact of human factors data upon system design and development was obtained from the observation that many contractors had already taken steps to alleviate the difficulties imposed by large quantities of human factors data by automated storage, retrieval, and processing. For example, Contractors 3 and 5 were using computers for the analysis of test data, Contractor 2 for system simulation, Contractors 2 and 5 for storage and printout of PED data and forms, and Contractor 7 for mission simulation and for checking the accuracy of task analyses and allocation.

SECTION IV

HUMAN FACTORS DATA NETWORKS

Data networks refer to that complex of data sources, generators, and users which, together with the methods of processing and transfer, and the points of interaction with system development, are necessary to assure the proper integration of human factors data in the development of a system.

Networks vary (as one would suspect, and as we have confirmed by our surveys), between systems, with time, and to some extent according to the idiosyncrasies of manufacturers, agencies, and individuals. Differences occur in methods of communication and delivery of data, amounts of data, and methods of storage. In the design of a system that is useful universally, the similarities are more important. The similarities provide the base for the design of a standard data handling system. This section describes a generalized network and its parts. All systems observed in our survey could operate within the framework of the generalized network described despite any of the differences mentioned above. This presentation is based on the integrated findings of the literature review, the interviews, and the questionnaires.

For descriptive purposes the major parts of a network will be referred to as components. Seven major components are required to describe fully a generalized network. These seven components and the gross relationships which hold among them are diagrammed in Figure 1. Subdivisions of the components are referred to as elements. The components are described in detail in the paragraphs to follow. They are seven in number and for convenience they will be referred to by use of these names.

1. Group I Data (a)
2. Generators
3. Group II Data
4. System Development Milestones
5. Users
6. End Items
7. Group I Data (b)

Group I Data (a)

Group I data are those which exist prior to the existence and/or independent of any specific system being developed. They include that

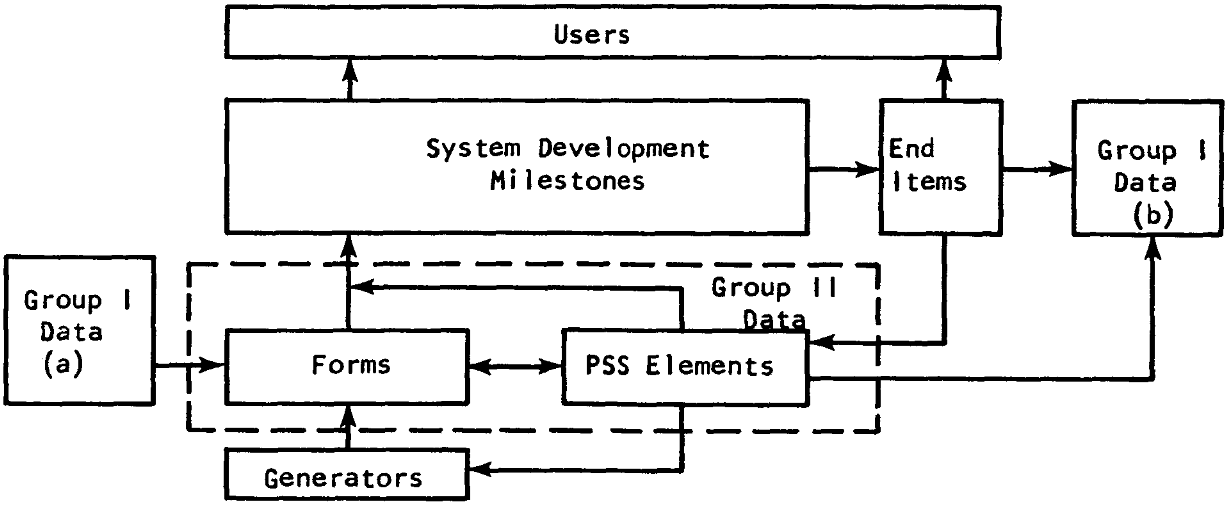


Figure 1. Relationship of data network components. Group II data are composed of two major sub-components, which are enclosed by the dashed line.

body of data included in handbooks; research reports; manuals of operation and maintenance, and other documents generated in the development of former systems; and private data which exist "in the heads" of engineers and other specialists responsible for system development.

These data are the foundation upon which all system-specific data are based. Many data exist in this "pool" but only a small part of them are used for any one system. The principal sources of these data are as follow:

Handbook Data

These are data found in reference works which summarize research findings and which are referred to frequently by engineers working on the systems studied. The ones used most frequently as indicated by both interview and questionnaire data include (6, 7, 4, and 5). These works are important in that they are referred to directly and frequently. In addition they form a basis for much "in-the-head" data as users become familiar, through frequent use, with data presented in them.

Research Reports

Reference is made about as frequently to this source of data as to handbooks. According to interviewees the probability of the use of this source depends largely on the personal inclinations and diligence of the individual. If handbooks as described above covered their areas adequately, one would have only to make reference to research reports in order to update or expand material found in the handbooks. Research reports refer only to published research documents, irrespective of publisher and/or distribution. Obviously, the availability of such reports varies greatly. The shelf space required even for those research reports which are generally available is much greater than that required for handbook summaries. Several of the manufacturers visited had extensive human factors libraries which usually were associated with a complete technical library.

Data Generated for Other Systems

Many data generated in system development can be useful in the planning and development of subsequent systems. This group includes some kinds of data (such as results of experimental investigations and empirical observations of performance) which, in an efficient system, should be included in a general data handling system. System managers at one of the contractors (No. 3) visited were supplied with large amounts of maintenance information collected in the operation of other systems. Personnel at another contractor (No. 5) indicated that access to QQPRI and maintainability analyses developed for a system already operational, would have been very useful to them in the development of a current project. They did not know if such records existed but suspected that they did. Access to these records is sufficiently difficult to make them virtually nonexistent for all but a very limited number of human factors personnel. There is a general feeling among personnel that there is a great amount of data which must have been generated in the course of development of former systems which are not generally available. When they are available, often they are in a form which requires extensive processing so that it is just as cheap to generate the data again.

Regulations and Manuals

This group of publications includes documents prepared by government agencies and used for the guidance of both government and contractor efforts in system development. They establish standards, supply basic data, and prescribe procedures for many activities which occur in the course of system development. These documents vary in specificity of guidance provided and allow for interpretation of the contents. This in turn accounts for some differences in procedures at different contractors' plants, though the contractors may have been governed by the same document.

Private Data Sources

Private data refer to information which is used in design and development and which is "in the heads" of generators and users. These data serve as an indication of the individual's (or manufacturer's) past training and experience which makes it possible for him to do the job assigned to him. The content of these data covers the range of data from other sources and often obviates the necessity for direct referral to other sources.

Another kind of private data takes the form of recorded information collected or noted by an individual but which has never been transmitted to anyone else because of the time-consuming efforts required for publication or wide distribution of any kind.

The content of these data sources as used by human factors specialists can be divided in 14 general areas which represent the information classes in which human factors specialists and the users of human factors data are interested. Information from any of these areas can be found in all of the forms just described. A more detailed schematic presentation of these areas of interest and the forms of data sources is presented in Figure 1a. This figure relates their data base to all other components of the generalized human factors network. The areas indicated are a consolidation of chapter headings in handbooks, human factors department names, classifiers used in classification systems in existence, and common areas of human factors interest. All data content observed in the survey can be classified in at least one of these areas. Identification of these general areas and a brief description of the content in each area follow.

1. Anthropometry. In this area the primary interest is in dynamic and static measurements of the human physique, with descriptors necessary to identify the populations to which reported measurements are applicable. Static measurements have to do with the body at rest in different positions while dynamic measurements indicate capabilities of movement in terms of rotation, flexion, extension, etc., and capabilities in terms of forces which can be applied under different conditions.

2. Environmental Parameters. This area includes those dimensions of the environment associated with the content of the atmosphere (gaseous, moisture), its physical characteristics (temperature, pressure), and the forces acting on the environment (gravity, vibration), as well as psychological conditions peculiar to the situation (e.g., stress, isolation, sensory deprivation).

3. Life Support. This area is related to the study of various hazards to human performance in a situation and the measures used to counter them, and the definition of conditions necessary to assure not only survival, but the reliable performance of assigned functions.

4. Logistics. This area has to do with the procurement, storage, distribution, and use of supplies and equipment necessary to support the human in the functions assigned.

5. Maintenance Design. This area includes all the variables considered in the design of all equipment associated with a system and which is related to the problem of maintaining the operation of the system at an acceptable level of efficiency. A few of these are accessibility of components, design of covers and cases, weight of movable parts, location of check points, and failure rates.

6. Operational Design. This area includes the variables related to the reliability and efficiency of the operation

of both primary and ancillary equipments. The relevant aspects include both gross and detailed consideration of controls and instrument displays.

7. <u>Performance Aids</u>. This area consists of the variables considered in the development of the various aids used by the human in fulfilling his assigned function. It includes the characteristics of informational aids such as manuals, checklists, instructions, etc., and the physical design of special tools.

8. <u>Personnel Equipment</u>. This area is concerned with the design and use of special clothing (space suits), safety devices (parachutes), and protective equipment (personal armor) intended for the use of all types of personnel necessary to safe and efficient system operation.

9. <u>Personnel and Manning</u>. This area is concerned with all the kinds of information necessary to determine the numbers, types (skill levels, training required), physical characteristics, and availability of personnel necessary for operation of a system.

10. <u>Proficiency Measurement</u>. This area has to do with the determination of appropriate measures and methods of obtaining measures useful in evaluating the efficiency or reliability of the human in the performance of his assigned function.

11. <u>Task and Performance Description</u>. Included in this area of interest are all those descriptors necessary to describe in detail the necessary prerequisites for the performance of a task, the task itself, and the consequences of performance of the task. It must include both temporal and spatial data as well as behavior descriptors.

12. <u>Training</u>. This area includes the classes of information which are related to the definition of training programs and curricula, specification for needed aids, training locations, training personnel, and criteria for completion of training.

13. <u>Training Equipment and Aids</u>. This group of information includes that used in designing and developing hardware and ancillary equipment used in training. It includes data relevant to the effectiveness of trainers, training accessories, and training parts.

14. <u>Workspace Layout</u>. This class of data includes all the variables considered in the design of job stations,

ABBREVIATIONS:

ADO	Advanced Development Objective
AFSCSO	Air Force Service Command System Office
ATCSO	Air Training Command System Office
CMD	Contract Management District
DDE	Deputy Director Engineering
DDPP	Deputy Director Procurement and Production
DDTD	Deputy Director Test and Development
ECP	Engineering Change Proposal
HE	Human Engineering
LS	Life Sciences
MA	Manpower Authorization
OSR	Operational Support Requirement
PCD	Program Control Division
PCP	Program Change Proposal
PS	Personnel Subsystem
PSPP	Proposed System Package Plan
PSTE	Personnel Subsystem Test and Evaluation
PTDP	Preliminary Technical Development Plan
QQPRI	Qualitative and Quantitative Personnel Requirements Information
SDD	System Definition Directive
SMTPR	System Manning and Trained Personnel Requirements
SOR	Specific Operational Requirement
SPD	System Program Director
SPO	System Program Office
SPP	System Package Program
SSM	System Support Manager
TC	Training Concept
TED	Training Equipment Development
TEPI	Training Equipment Planning Information
TF	Training Facilities
TP	Training Plans
TPR	Trained Personnel Requirements
USCO	Using Command

LEGEND:

———————— Training Network

——— ——— HE/LS Network

—— —— —— —— Personnel Network

These networks chosen for diagram as being most representative and inclusive.

Note:

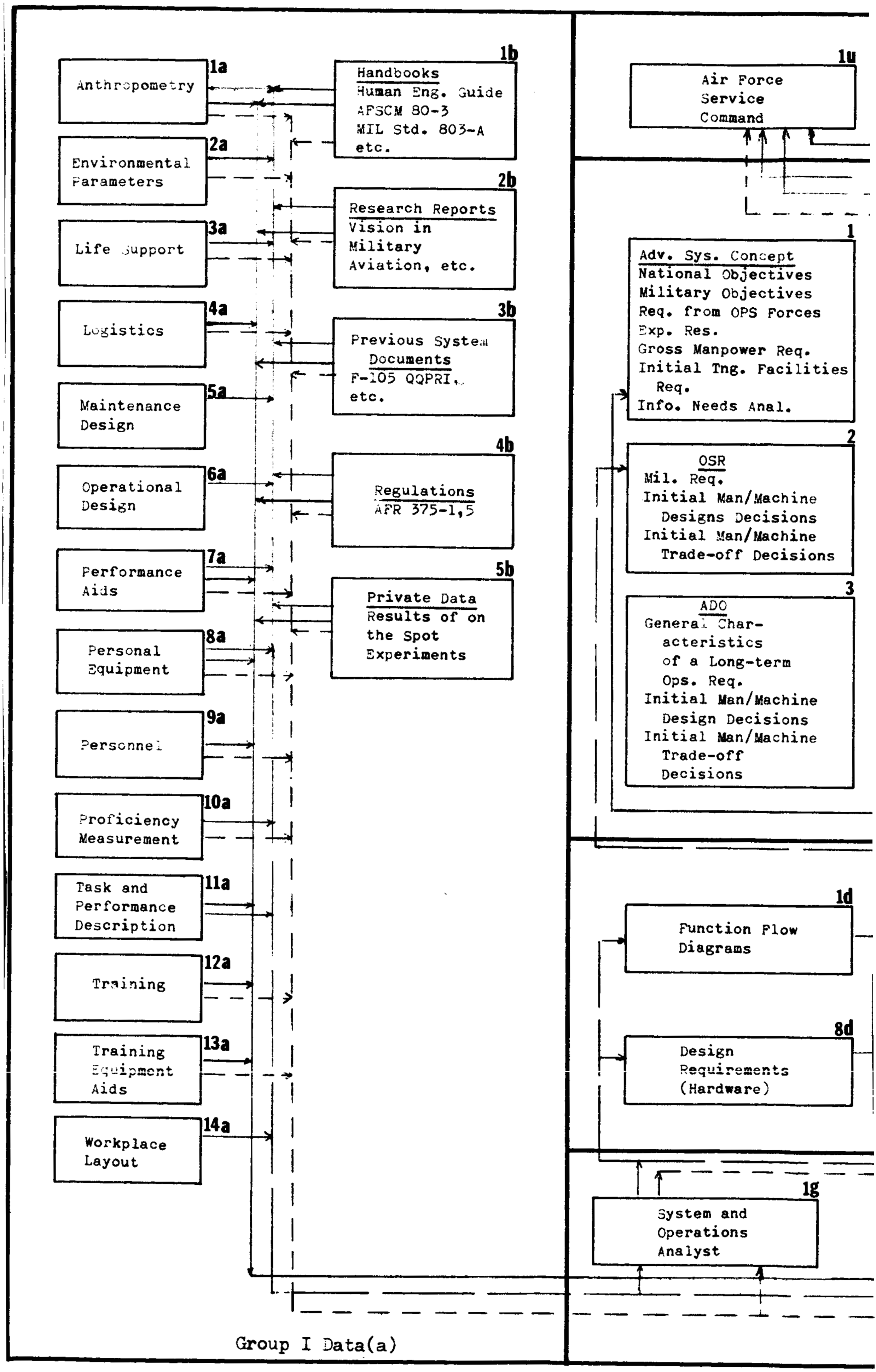
In system milestone area, flow is direct from top to bottom in end column of elements and proceeding to top of next column. Numbers at right of element indicate feedback to numbered element. Numbers at left indicate source of feedback.

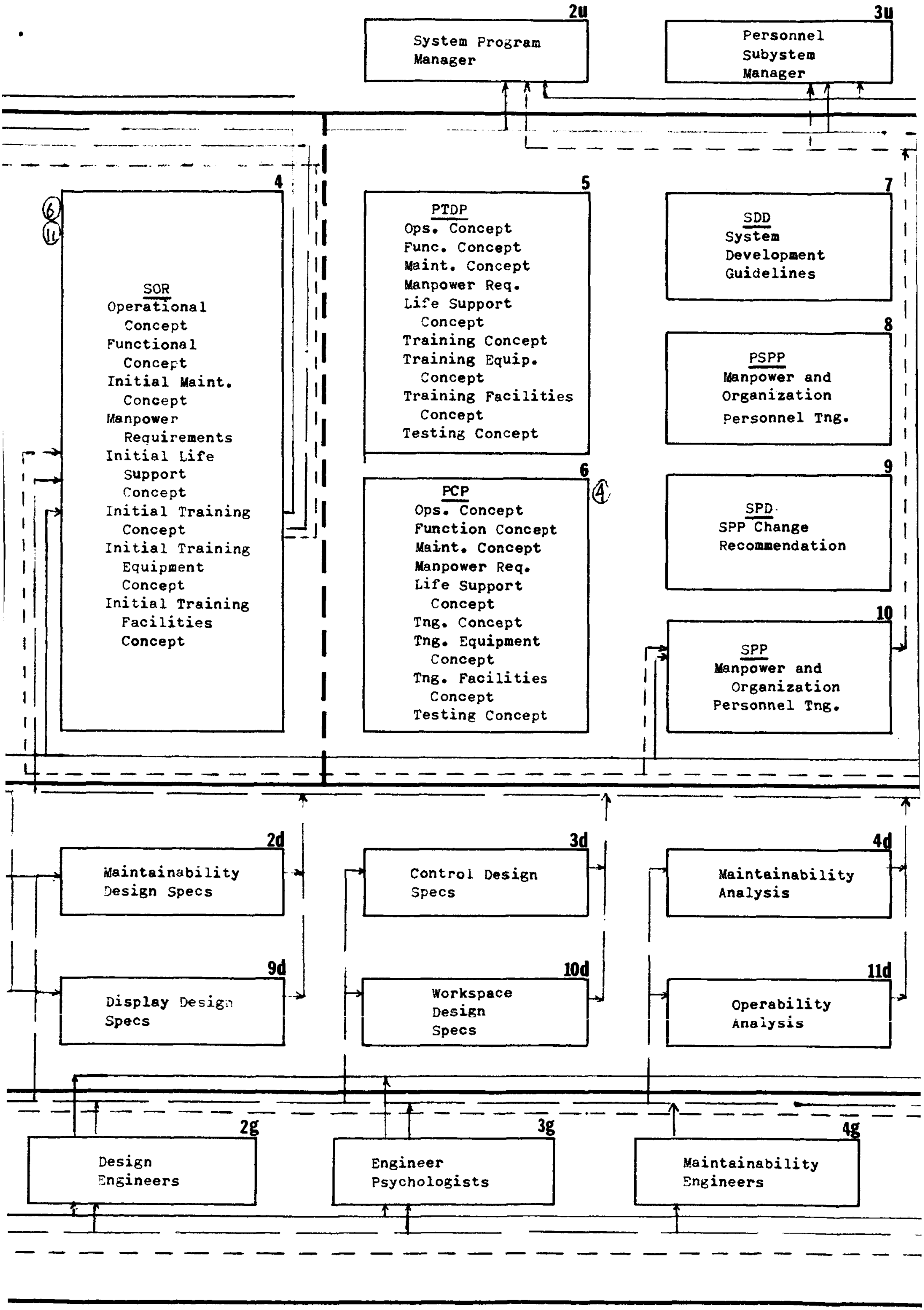
Subscripts indicate components:

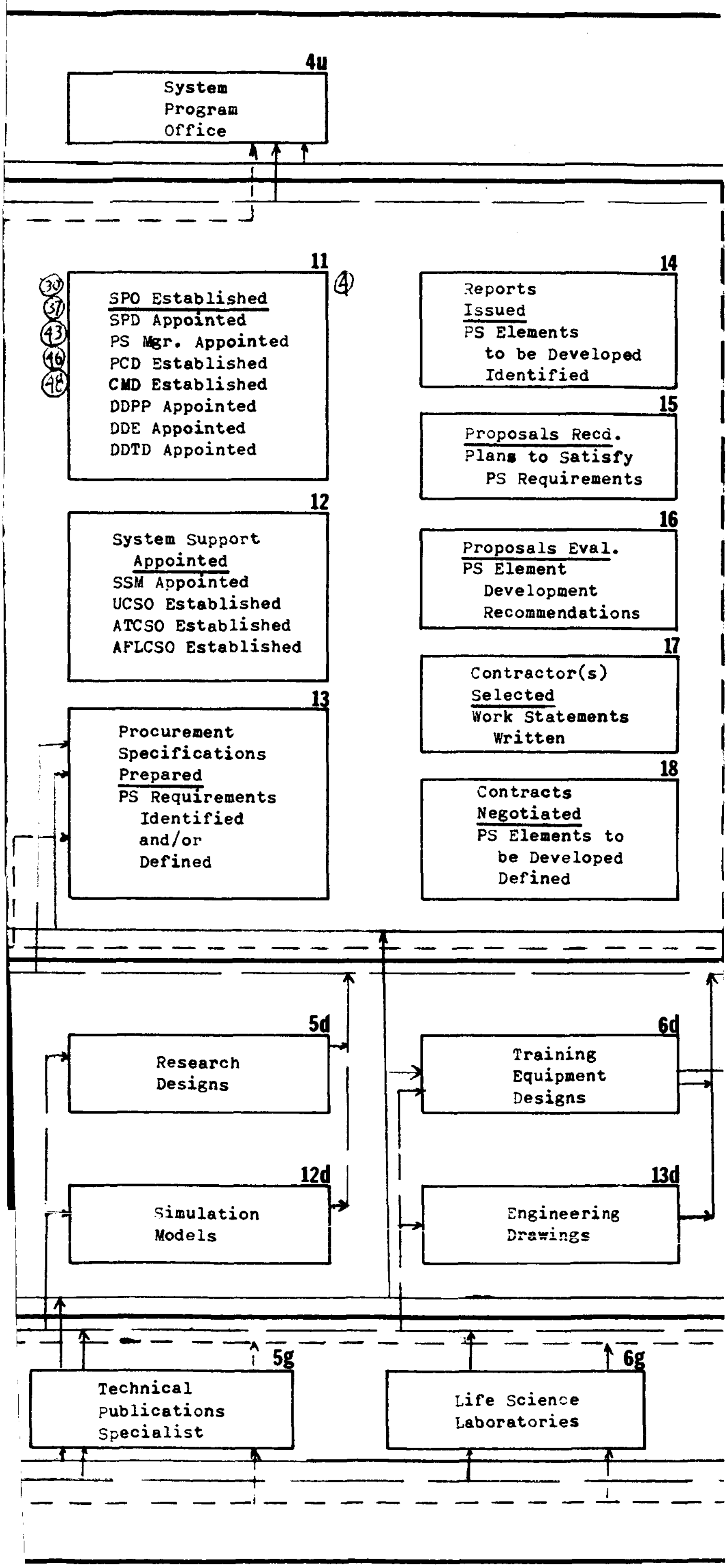
a. Group I Data (areas)
b. Group I Data (sources)
c. End Items
d. Group II Data (Design)
e. Group II Data (Personnel Subsystem)
g. Generators
u. Users

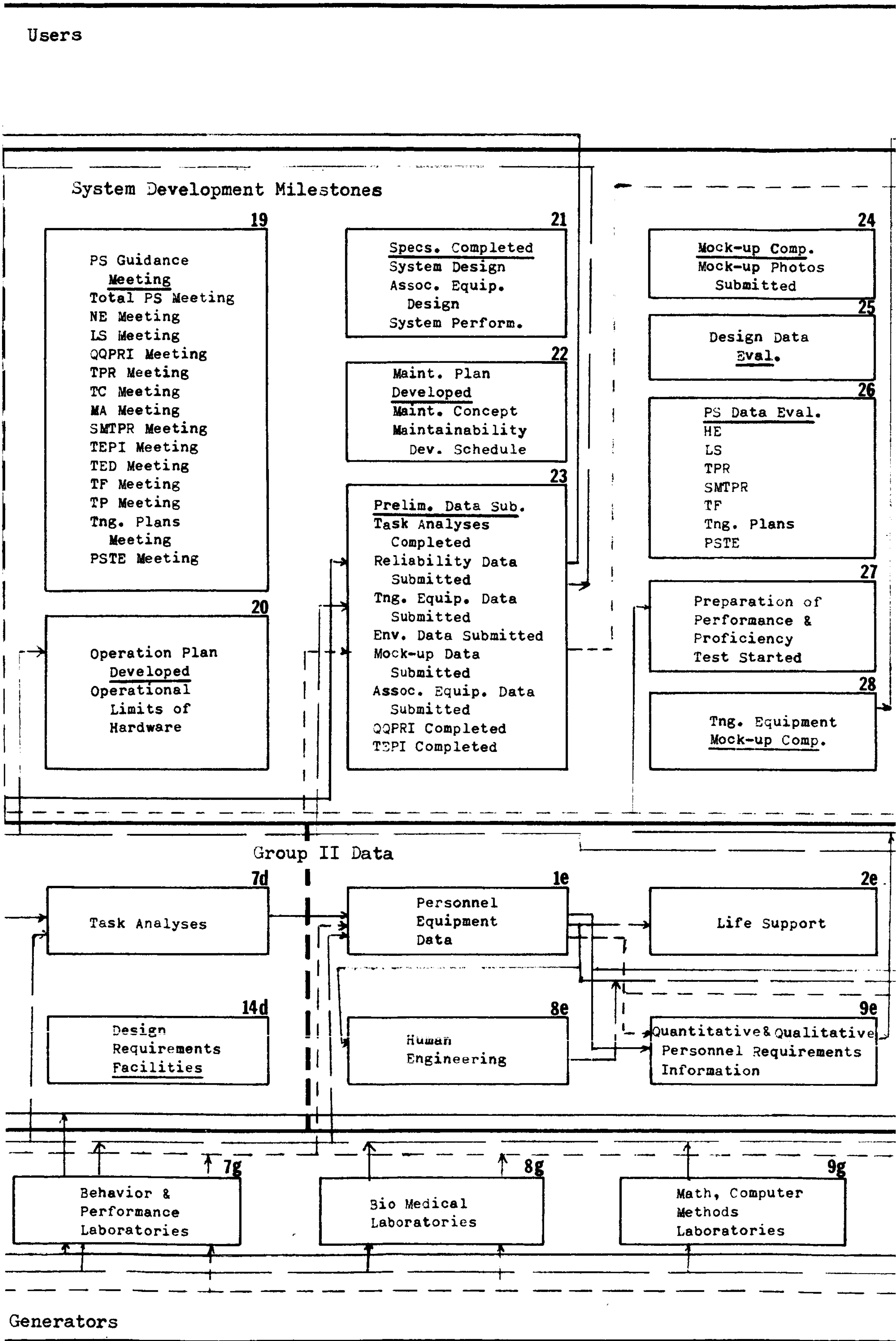
No subscripts indicate development milestones.

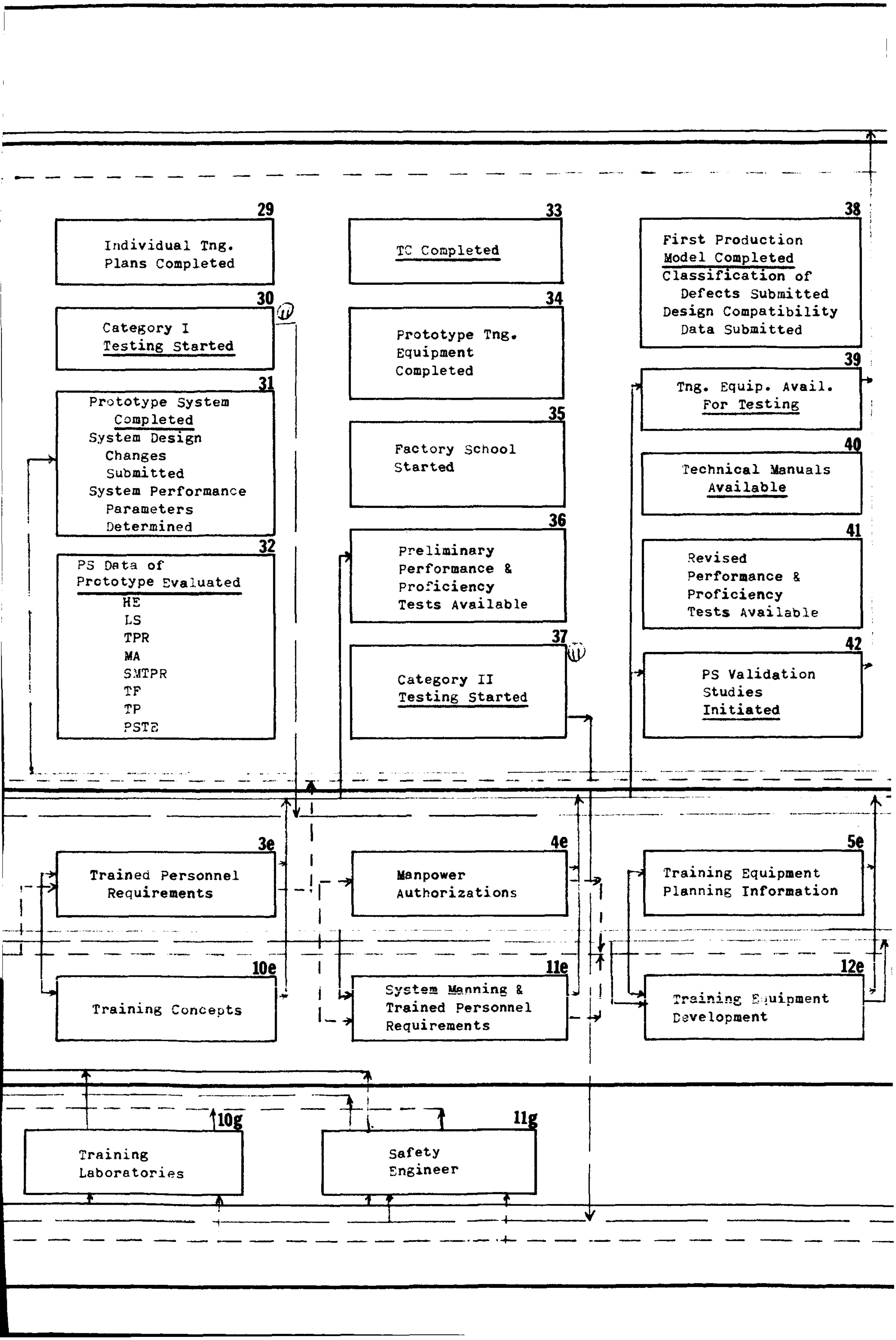
Figure 1a. Detailed network schematic.

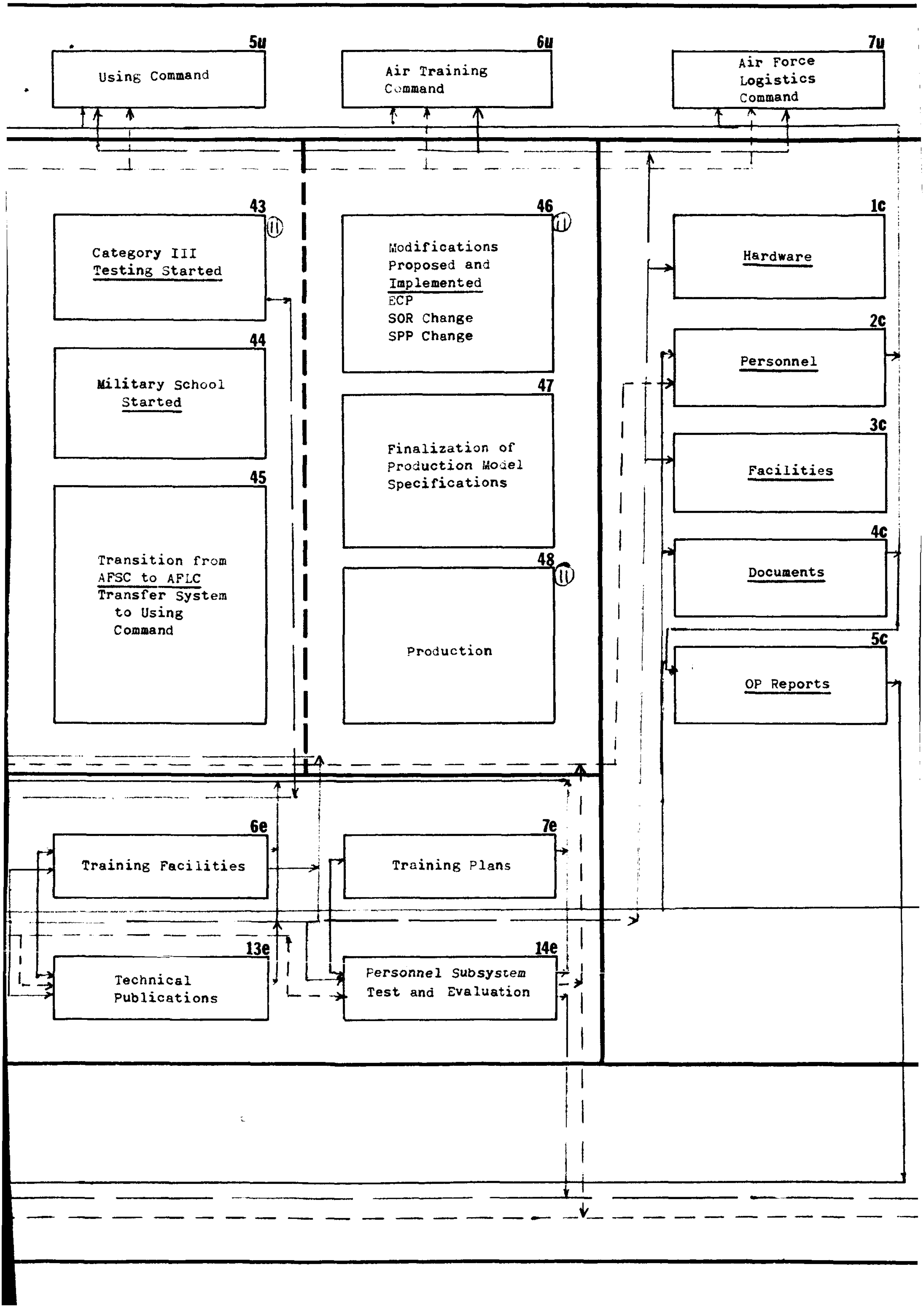

1a Anthropometry
2a Environmental Parameters
3a Life Support
4a Logistics
5a Maintenance Design
6a Operational Design
7a Performance Aids
8a Personal Equipment
9a Personnel
10a Proficiency Measurement
11a Task and Performance Description
12a Training
13a Training Equipment Aids
14a Workplace Layout
1b Handbooks
Human Eng. Guide
AFSCM 80-3
MIL Std. 803-A
etc.
2b Research Reports
Vision in Military Aviation, etc.
3b Previous System Documents
F-105 QQPRI,
etc.
4b Regulations
AFR 375-1,5
5b Private Data
Results of on the Spot Experiments
Group I Data(a)
1u Air Force Service Command
1 Adv. Sys. Concept
National Objectives
Military Objectives
Req. from OPS Forces
Exp. Res.
Gross Manpower Req.
Initial Tng. Facilities Req.
Info. Needs Anal.
2 OSR
Mil. Req.
Initial Man/Machine Designs Decisions
Initial Man/Machine Trade-off Decisions
3 ADO
General Characteristics of a Long-term Ops. Req.
Initial Man/Machine Design Decisions
Initial Man/Machine Trade-off Decisions
1d Function Flow Diagrams
8d Design Requirements (Hardware)
1g System and Operations Analyst

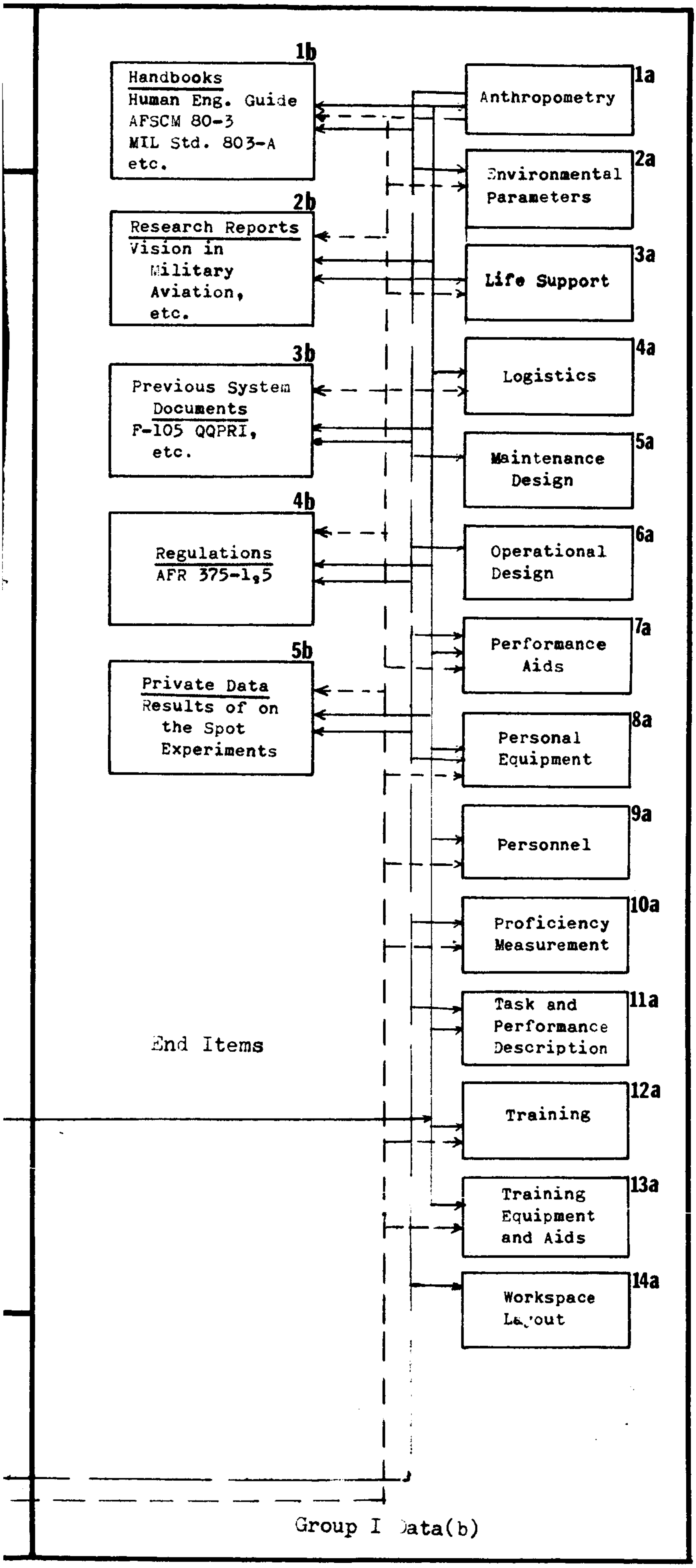

2u
System Program Manager
3u
Personnel Subystem Manager
4
6
11
SOR
Operational Concept
Functional Concept
Initial Maint. Concept
Manpower Requirements
Initial Life Support Concept
Initial Training Concept
Initial Training Equipment Concept
Initial Training Facilities Concept
5
PTDP
Ops. Concept
Func. Concept
Maint. Concept
Manpower Req.
Life Support Concept
Training Concept
Training Equip. Concept
Training Facilities Concept
Testing Concept
6
4
PCP
Ops. Concept
Function Concept
Maint. Concept
Manpower Req.
Life Support Concept
Tng. Concept
Tng. Equipment Concept
Tng. Facilities Concept
Testing Concept
7
SDD
System Development Guidelines
8
PSPP
Manpower and Organization
Personnel Tng.
9
SPD
SPP Change Recommendation
10
SPP
Manpower and Organization
Personnel Tng.
2d
Maintainability Design Specs
3d
Control Design Specs
4d
Maintainability Analysis
9d
Display Design Specs
10d
Workspace Design Specs
11d
Operability Analysis
2g
Design Engineers
3g
Engineer Psychologists
4g
Maintainability Engineers


4u
System Program Office
11
SPO Established
SPD Appointed
PS Mgr. Appointed
PCD Established
CMD Established
DDPP Appointed
DDE Appointed
DDTD Appointed
30
37
43
46
48
4
12
System Support Appointed
SSM Appointed
UCSO Established
ATCSO Established
AFLCSO Established
13
Procurement Specifications Prepared
PS Requirements Identified and/or Defined
14
Reports Issued
PS Elements to be Developed Identified
15
Proposals Recd.
Plans to Satisfy PS Requirements
16
Proposals Eval.
PS Element Development Recommendations
17
Contractor(s) Selected
Work Statements Written
18
Contracts Negotiated
PS Elements to be Developed Defined
5d
Research Designs
12d
Simulation Models
6d
Training Equipment Designs
13d
Engineering Drawings
5g
Technical Publications Specialist
6g
Life Science Laboratories


Users
System Development Milestones
19
PS Guidance Meeting
Total PS Meeting
NE Meeting
LS Meeting
QQPRI Meeting
TPR Meeting
TC Meeting
MA Meeting
SMTPR Meeting
TEPI Meeting
TED Meeting
TF Meeting
TP Meeting
Tng. Plans Meeting
PSTE Meeting
20
Operation Plan Developed
Operational Limits of Hardware
21
Specs. Completed
System Design
Assoc. Equip. Design
System Perform.
22
Maint. Plan Developed
Maint. Concept
Maintainability
Dev. Schedule
23
Prelim. Data Sub.
Task Analyses Completed
Reliability Data Submitted
Tng. Equip. Data Submitted
Env. Data Submitted
Mock-up Data Submitted
Assoc. Equip. Data Submitted
QQPRI Completed
TEPI Completed
24
Mock-up Comp.
Mock-up Photos Submitted
25
Design Data Eval.
26
PS Data Eval.
HE
LS
TPR
SMTPR
TF
Tng. Plans
PSTE
27
Preparation of Performance & Proficiency Test Started
28
Tng. Equipment Mock-up Comp.
Group II Data
7d
Task Analyses
1e
Personnel Equipment Data
2e
Life Support
14d
Design Requirements Facilities
8e
Human Engineering
9e
Quantitative & Qualitative Personnel Requirements Information
7g
Behavior & Performance Laboratories
8g
Bio Medical Laboratories
9g
Math, Computer Methods Laboratories
Generators


29
Individual Tng. Plans Completed
30
Category I Testing Started
31
Prototype System Completed
System Design Changes Submitted
System Performance Parameters Determined
32
PS Data of Prototype Evaluated
HE
LS
TPR
MA
SMTPR
TF
TP
PSTE
33
TC Completed
34
Prototype Tng. Equipment Completed
35
Factory School Started
36
Preliminary Performance & Proficiency Tests Available
37
Category II Testing Started
38
First Production Model Completed
Classification of Defects Submitted
Design Compatibility Data Submitted
39
Tng. Equip. Avail. For Testing
40
Technical Manuals Available
41
Revised Performance & Proficiency Tests Available
42
PS Validation Studies Initiated
3e
Trained Personnel Requirements
4e
Manpower Authorizations
5e
Training Equipment Planning Information
10e
Training Concepts
11e
System Manning & Trained Personnel Requirements
12e
Training Equipment Development
10g
Training Laboratories
11g
Safety Engineer


5u
Using Command
6u
Air Training Command
7u
Air Force Logistics Command
43
Category III Testing Started
11
44
Military School Started
45
Transition from AFSC to AFLC Transfer System to Using Command
46
Modifications Proposed and Implemented
ECP
SOR Change
SPP Change
11
47
Finalization of Production Model Specifications
48
Production
11
1c
Hardware
2c
Personnel
3c
Facilities
4c
Documents
5c
OP Reports
6e
Training Facilities
7e
Training Plans
13e
Technical Publications
14e
Personnel Subsystem Test and Evaluation


1b
Handbooks
Human Eng. Guide
AFSCM 80-3
MIL Std. 803-A
etc.
2b
Research Reports
Vision in
Military
Aviation,
etc.
3b
Previous System
Documents
F-105 QQPRI,
etc.
4b
Regulations
AFR 375-1,5
5b
Private Data
Results of on
the Spot
Experiments
End Items
1a
Anthropometry
2a
Environmental
Parameters
3a
Life Support
4a
Logistics
5a
Maintenance
Design
6a
Operational
Design
7a
Performance
Aids
8a
Personal
Equipment
9a
Personnel
10a
Proficiency
Measurement
11a
Task and
Performance
Description
12a
Training
13a
Training
Equipment
and Aids
14a
Workspace
Layout
Group I Data(b)

especially as regard the use of available space, provision of necessary supports, shielding, and the coordination of workspace for multi-man crews.

This Group I data base contains all the different forms and levels of data and covers all the subject matter areas with which human factors in system development are concerned. It is never fixed in content; rather, it is constantly in the process of being revised and enlarged, not only as new systems are developed, but as independent research both basic and applied, and experience in training personnel and operating systems supply new and better information. That the Group I data pool is different at the phase-out of any one system than it was before the existence of the system is shown schematically in Figures 1 and 1a by the cells which represent Group I data and which reappear at the right side of the figure.

Elements in Figure 1a with subscript a represent the data areas. Elements with subscript b are the principal data sources as previously described. Since these kinds of sources are practically universally used, they are joined in the flow diagram to all of the diagrammed networks.

Generators

Generators of human factors data are all those individuals who provide any part of the large heterogeneous body of information subsequently identified as human factors data in the context of system development. When all data are traced to their primary sources, the generator group must include members of all scientific and technical disciplines. For the purposes of this discussion, only those generators whose outputs are concerned directly with system development will be considered.

The primary specialties of individuals (generators) contacted by direct interview or by questionnaire ranged through engineering, psychology, writing, medicine, statistics, administration, computer programming, teaching, flying, and mechanics. A characteristic of most individuals contacted was competency in more than one field. Although there were many combinations of the fields mentioned, the most frequent, noted in interviews were, in the order mentioned, engineering and psychology, statistics and psychology, engineering and administration, engineering and writing, and psychology and writing.

Individuals who generate data are also prime users of both Group I and Group II data. Many of their functions are iterative and in practically all cases there are interactions between generators. One generator's output may become another's input, and two generators may work with the same input to produce different outputs.

Data generated within the context of system development are seldom identified as the output of a single individual. More often they are associated with the efforts of a section identifiable as a group of individuals with a specific assigned function. The specific name assigned to such a group varies from one contractor to another and from one government agency to another. The activities can generally be recognized, however, as being a function of one of the groups found in the cells identified as generators by the subscript _g_ in Figure 1a. These groups include:

Operators and Systems Analysts

Design Engineers

Maintainability Engineers

Safety Engineers

Engineering Psychologists

Life Science Specialists

Behavior and Performance Specialists

Mathematics and Computer Methods Specialists

Training Specialists

Technical Publications Specialists

Group II Data

Group II data are those which are generated within the development of a specific system, and include the forms used in the development process and products of the personnel subystems elements. While the content of these data is of the same nature as that in Group I data, the form in which they are transmitted from one activity to another or in which they are reported to management personnel and the users, is prescribed by regulations and specifications of government agencies and by established procedures of the various manufacturers. Despite a considerable variety of forms, the structure of the data is such that all of the information can still be categorized in terms of descriptors selected from the limited number of areas indicated in Group I data, since many kinds of items are common to many of the documents. Figure 1 indicates the general relationship of these data to the overall data network. Group II data, both generic types of data forms used and currently specified personnel subsystem elements, are diagrammed in Figure 1a and related to each other and to other components of the data network. The elements representing generic data forms are identified by subscript _d_, and standard personnel subsystem elements by subscript _e_.

System Development Milestones

This network component is a schematic representation of the steps in system development presented in sequence as determined by the time of their being initiated in the development cycle. Some of the cells represent concurrent activities which, once started, continue until the system is phased out.

Many steps or milestones in system development have been intentionally omitted from this presentation. Those included, however, have been selelected for their relevance to the human factors aspect of system development and represent points where human factors considerations are introduced in the system or where interactions related to human factors inputs take place. The feedback loops within the milestones are indicated by numbers which appear to the right of some of the cells. These numbers refer to cells appearing earlier in the sequence and to which the cells feed information. Numbers which appear to the left of a cell indicate cells other than the immediately preceeding one, which provide important inputs in the sequence. No subscripts are associated with these elements.

Users

The hierarchy of users as presented in the network diagram includes three levels which can be clearly differentiated according to the kind of function assigned in system development. The cells in the space labeled "users" include only the highest level and indicate people for whom all data, products, and the results of system development are prepared. The managers at this level seldom generate data except in the sense that they direct the total effort of a program or programs which result in the generation of data.

At the other end of the scale are those persons previously identified as generators, and labeled as generators in the figures, but who are prime users in that all of their outputs depend on use of data previously extant. They work with the basic data available at the start of system development, and with those generated within the system as it develops, to provide managers at all levels with the information they need. As was previously mentioned in the description of generators, there probably are no data generators who are not also users.

The third group is comprised of managers at the intermediate level of the hierarchy. In the figure they are represented only by the related system milestone cells. These persons are responsible for direction of generators and for regulating the flow of data through the systems components and to the ultimate users. Since they prepare reports, collate, condense, and evaluate data which guide the making of decisions and subsequent generation of other data, they can also be considered data generators. User elements in the diagram are identified by subscript u.

End Items

The end items are those items, the existence of which guarantees the continued efficient operation of a system once it has been acquired. These items are presented in Figures 1 and 1a as belonging to one of the following five classes of items:

1. Hardware. This includes all primary and ancillary equipment which must be developed, and operating

equipment, training equipment, tools, and spares, in sufficient quantity to keep the system operating at the specified level.

2. Personnel. These include all those persons necessary to operate and maintain the system.

3. Facilities. These include special installations as are required for operation of the system, such as associated buildings of all kinds, launching platforms or pads, and cranes, which are system-specific.

4. Documents. These include all the training, maintenance, operation, and installation manuals, checklists, instruction sheets, technical orders, and all other publications necessary for the operation of the system.

5. Operation Reports. These are the accumulation of reports of operation which, as they are developed, are used for evaluation of performance, correction of deficiencies, and recommendations for changes in methods of training and operation to continually improve the system.

The last two of these items are of prime importance in the data system as they provide data which become part of a general store and which can be useful in design of following systems. In particular the group of operational reports is used from the time operational testing of the first item of hardware begins, and provides the major feedback loop for updating information sources and providing bases for the evaluation of the personnel subsystem. These elements are identified in the figure with the subscript c.

Group I Data (b)

This group of data is the same as that described in Group I (a) and is shown to emphasize that any system developed can contribute to a general data store which will be useful to the developers of subsequent systems.

The network as diagrammed and explained was a composite of the components and elements common to networks examined. It was not intended to be a complete diagram of a particular system. Elements were selected which best showed the interactions of human factors data with system development as a whole. Air Force terms were used, since they are generally used and their meanings recognized by human factors specialists throughout industrial and the government agencies. As presented, the diagram showed the following things about human factors networks:

1. The data generators are usually not identified as human factors specialists.

2. The inputs used by generators come from Group I data and are supplemented by Group II data as development progresses.

3. Data generators recombine data from the common base to produce Group II or within-system data.

4. The data generated are required early in system development.

5. There are continuous feedback loops in which data are reprocessed throughout the iterative design processes.

6. Different users require human factors data from different points in system development.

7. The operational system feeds back data for purposes of test and evaluation.

8. An augmented common data pool exists at the completion of a system development cycle.

The lines on the diagram represent the direction of data flow. The three differentiated lines (see legend) indicate three separate networks. One represents the combined threads of human engineering/life sciences efforts, one represents personnel considerations, and one represents the training networks.

While the lines represent data flow, they do not indicate the nature of the flow. The following methods of transmitting data exist:

1. Preparation of formal documents on request and transmission by internal and public mail systems.

2. Preparation of formal documents on standard schedule and transmission by internal and public mail systems.

3. Accumulation of data by a central office which redistributes them on scheduled intervals to the next user of the data.

4. Accumulation of data by a central office and redistribution on a called-for or as-needed basis.

5. Phone calls or personal visits between generators and subsequent users.

6. Interchange of information between members of a design team working at adjacent desks.

7. Requests by phone, mail, or direct visit to libraries and established data sources.

8. Meetings of design teams at regular intervals or at a call to exchange data.

9. Reference to standard documents which an individual keeps at hand.

10. Required review of documents by human factors specialists to assure proper consideration of human factors (design sign-off requirement).

11. Evaluation of document for human factors consideration only when requested by engineering departments.

Some or all of these methods may be used in any system network. The chief differences between networks are the differential ways in which these methods are used. The centralized data store methods suffer from delays resulting from overload both in the quantity of data stored and in the number of demands made on them. The direct contacts between individuals in an attempt to speed communication lose efficiency in a large system because of the difficulty in identifying the person or section who might have the data needed by an individual or another section at any point in time. Many interviewees reported that there were times when previously generated data had been unavailable to them because they did not know whom to ask, and/or because the time required to go through the channels through which data were normally obtained was too long.

Some of these communications channels have been at least partially automated at several of the contractors visited. Two plants visited (Contractors 3 and 4) have centralized computer stores of personnel equipment data. One of these "dumps" the data at regular intervals for distribution. The other provides summaries "on call." Contractor 8 maintains a semi-automated library of technical documents. Interviewees at these plants felt that the systems are valuable but that, at the present time, the maximum utility is not obtained from them. This was usually attributed to lack of sophisticated programming and delays in entering data. The existence of these efforts do, however, indicate a trend toward the development of automated handling of human factors data.

SECTION V

DATA CLASSIFICATION

Although the uses made of human factors data are varied, as are the ways in which they are organized for use, the content is quite homogeneous as to characteristics of the items. Each item is related to certain kinds of behavior, performance, and equipment or workspace. The items can, therefore, be described in terms of a limited number of variables together with their associated measures. The chief differences from item to item are the particular equipments considered in relationship to the human and the particular variables considered in the relationship. Aside from these differences are those which exist in the form of the data and the level of detail presented. An apparent difference, though not a real one, is that of quantity of items presented in any one document or form. However, any document or form presenting an accumulation of a large number of items, can be divided into a series of separate items just as a large and complex matrix can be looked at cell by cell to describe its content.

A file system capable of accumulating all human factors data must be capable of storing data in all their various forms, at any one of several levels of detail, and in a way that they are retrievable by reference to their content. Level of detail can vary from general statements such as "a three man crew is required" to a complete specification of crew requirements including amount of training, age, weight, experience, and other qualifying items.

Form

The variety of forms which must be stored has implications for computer storage methods and materials which are only indirectly related to classification of the information, since the same information can be presented in different ways. The form of presentation is partly a function of the uses to be made of the data, partly of the personal preferences of the generator, and in some cases of the content. A storage system must be capable of storing data in any of the forms in which it occurs. Table IX names and describes the forms of data. Very often data appears in a combination of one or more of the forms.

Selection of Categories

The selection of categories and subcategories is a critical part of the development of a centralized data store. It is important that categories be used which are appropriate to the content of the data and the uses made of them. At the present time no universal method of classifying all human factors task, performance, and related data exists.

Table IX

FORMS OF DATA

Form	Characteristics	Examples
Standard forms as required by regulations, etc.	Highly formatted information	Task analyses, maintenance analyses, malfunction reporting forms
Narrative reports	Verbal descriptions of situations or requirements or results of study	Some specifications, journal articles, oral communication
Engineering drawings	Line drawings showing scale plans of relevant equipment	Panel layout plans
Isometric drawings	Line drawings showing relationships of parts and/or operators	Crew position diagrams, control operation pictorials
Schematic drawings	Formalized diagrams showing functional relationships of elements of systems and subsystems	Flow charts, functional analyses
Graphs	Bar or line graphs which present experimental results	Bar graphs showing manning requirements at various military installations
Tables	Large amounts of data, usually numerical, presented in column or matrix form	Summarized results of investigations, math. tables
Discrete information units with one variable	Simple statements of fact or direct relationship	Data extracted from table or report
Discrete information units with more than one variable	Statements of fact relating more than one variable	Data extracted from table or report

Formal and detailed classification schemes exist only for small areas of the field and these are not universally recognized as being acceptable. Lovinger and Baker (8) present an analysis of the most frequently used handbooks indicating specific deficiencies of those handbooks and, by extension, deficiencies of classification systems. Their analysis focuses on the same literature identified as that most frequently used by the population in our survey.

In order to overcome the inadequacies outlined in (8) a data store should be organized in a way that:

1. Provides basic and quantitative data.

2. Is current.

3. Is organized around human functions.

4. Is specific to engineering design details.

5. Is analytical.

6. Provides technical accuracy and consistency.

7. Uses a standardized terminology.

In view of these criticisms and conclusions it would be presumptuous to try to develop a detailed classification scheme for a data bank as a part of this presentation. This is especially true since the development of such a list would necessarily depend on extant schemes which have been found to be inadequate. A classification scheme which would meet the requirements suggested (8) should be developed in consultation with boards of experts in each of the areas identified as being in the human factors domain and who have had experience applying data in a system context. Once a basic classification scheme has been developed and put in use in an automated data bank, a program could be developed for automatic refinement and updating of the system.

Data, in addition to being classified according to content, must be associated with information which relates them to their source or origin, specific hardware and/or situation, and their identification as part of a specific body of data related to a specific document. In addition they must be classified to indicate security or proprietary restrictions.

When the data are associated with operator tasks they must also be associated with relevant time measures which indicate both duration and order of the task to facilitate studies of time/operator-shared tasks and mission simulations.

Within the limitations imposed and in view of the requirements for a classification as just discussed, the following suggested categories have been developed from a collection of task description formats and data classification systems in current use. To become part of a useful store, data must be classified according to all the appropriate categories in this list and stored in a way that retrieval by single categories and selected combinations of categories where interactions are important is possible. Such a system can constitute the basis for development of a flexible and useful data bank.

Recommended Categories

The kinds of categories required to classify data can be divided into the following groups: hardware identifiers, function identifiers, data origin identifiers, task data (behavior personnel), task data (descriptors), and associated human factors areas.

Group I Hardware Identifiers

The first group of these categories serves to relate the stored data to hardware. This information is not human factors specific, but serves to identify particular equipment for which data are generated. Classifying and storing data in this way makes possible the comparison of selected areas across systems. Provision should be made for the small parts of equipment. Identification should be possible by generic name, specific name, and part number.

Required Classifiers Group I

1. System, generic name, specific name, number

2. Subsystem, generic name, specific name, number

3. Assembly-component generic name, specific name, number

4. Subassembly-subcomponent, generic name, specific name, number

5. Part, generic name, specific name, number

Group II Function Identifiers

Function identifiers, which form the second group of categories are important since the same task assignment may result in different performance when carried out in different operational contexts. Since mission designation can cover a series of activities, it is necessary to identify small sections of a total mission.

Required Classifiers Group II

6. Mission

7. Phase

8. Phase segment

9. Manuever - Assignment

10. Function

Group III Data Origin Classifiers

The third group of categories are those which have to do with the origin and classification of the data and is not directly related to the data content. This group includes classifiers which relate associated stored items as, for example, the subtasks descriptions of a task or a sequence of related events. It also includes provision for indicating the restrictions placed on dissemination of the stored data.

Required Classifiers Group III

11. Entry date

12. Date generated

13. Author

14. Document name

15. Document source

16. Document classification

17. Revision number

18. Data line number

19. Location (in data bank) or referenced documents

20. Associated data entries

21. System development phase

Group IV Personnel Identifiers

The fourth group includes classifiers necessary to describe the personnel performing a particular task described in the data file entry. Personnel variables other than listed here should be placed in the last group of categories to be described. Provision for an individual's name is also included, since in space systems it is possible that only a very few individuals will be trained and responsible for performing a certain task.

Required Classifiers Group IV

22. Job title

23. AFSC (or specialty number or code)

24. Associates required (if task is dependent on more than one person)

25. Special training required (for behaviors beyond level of or not provided for in AFSC)

26. Name of individual

Group V Task Description Identifiers (Behavior)

The fifth group included those items which make up a traditional task description. It includes classifiers which relate the behavior to parts acted on or with, as well as duration and sequence indicators. Indication of the level of detail of stored data should be related to this group of identifiers. Indication of level can be made by identifying the entry as a job, task, sub-task, or task element. This should be tied directly to the task verb.

Required Classifiers Group V

27. Task (verb-level)

28. Task (object)

29. Time to perform

30. Time relative to zero point in sequence

31. Sequence number

32. Frequency

33. Reliability

34. Criticality

35. Uniqueness

36. Tools and aids required

37. Initiation indicator

38. Completion indicator

Group VI Human Factors Variables

The final group of identifiers includes those areas of information which provide the basic data related to tasks and in which human factors specialists are interested. From these categories also are derived data for application to specific problems. New data are contributed to these categories as a result of human factors specialists' efforts. The subcategories of these major categories constitute the many variables related to human factors task data. In most cases mention of a variable must be associated with a measure. It can be seen that within these areas of information there can be variables in one area directly related to variables in another area. A storage system should be able to indicate these relationships when they exist. Development of the classification of these variables together with associated relevant measures should be accomplished, as has been previously mentioned, in close consultations with experts intimately familiar with the subject matter and who are experienced in applying the data to system development.

Required Classifiers Group VI

39. Anthropometry

40. Environmental parameters

41. Life support

42. Logistics

43. Maintenance design

44. Operability design

45. Performance aids

46. Personnel equipment

47. Personnel

48. Proficiency measurement

49. Training

50. Training equipment and aids

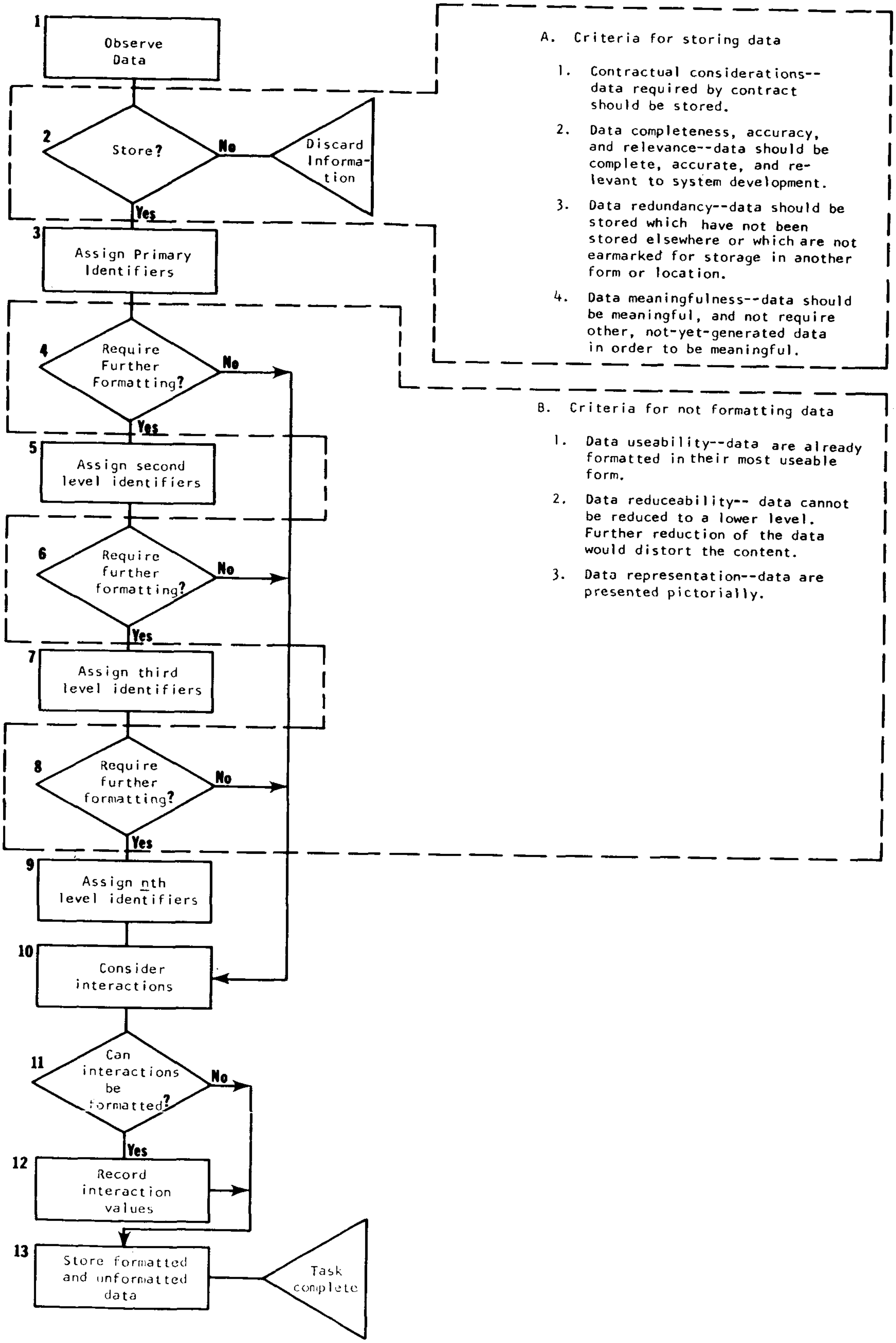
51. Workspace layout

Classification and Storage Procedures

In order to be amenable to storing -- that is, that the task of preparing data for entry in a storage system is not so formidable as to discourage use of the system -- some guidelines for classifying data by areas of information contained and the level of detail appropriate must be provided. The suggestions which follow are appropriate to whatever final form any storage system might take. The series of decisions which must be made are presented schematically in Figure 2.

The first decision which must be made by a user who has the opportunity or assignment to store data is that of deciding whether or not the

Representative Criteria for Decisions
Regarding Storing and Formatting
Data



A. Criteria for storing data

1. Contractual considerations--data required by contract should be stored.
2. Data completeness, accuracy, and relevance--data should be complete, accurate, and relevant to system development.
3. Data redundancy--data should be stored which have not been stored elsewhere or which are not earmarked for storage in another form or location.
4. Data meaningfulness--data should be meaningful, and not require other, not-yet-generated data in order to be meaningful.

B. Criteria for not formatting data

1. Data useability--data are already formatted in their most useable form.
2. Data reduceability-- data cannot be reduced to a lower level. Further reduction of the data would distort the content.
3. Data representation--data are presented pictorially.

Figure 2. Classification decision diagram.

data he considers should, in fact, be stored. Reference to the figure will show the criteria for making this decision (Section 2 in Figure 2).

If the decision is made to store the data the next step is to decide whether or not the data should be stored in their existing form or whether they should be formatted. If they are to be stored in their existing form they must be tagged with first level identifiers for each of the required categories. A suggested form for presenting these identifiers to the coder (for any storage system) is presented in Figure 3.

If the data require further formatting, tagging descriptors must be selected from second level descriptors for each of the human factors areas listed. A sample list of second order descriptors for the training area is presented in Table X. As shown in Figure 2 this process is iterative. It can be carried out to the number of levels of subcategories which experts in each field indicate are required.

The final decision to be made concerns interactions among variables in the human factors areas. The process is presented schematically in cells 10, 11, 12 of Figure 2. A form suggested for indicating interactions to the data coder is presented in Figure 4.

The exact nature of coding forms must be determined in conjunction with hardened design of a data handling system including both the hardware and software associated with such a system.

1. System Relevance

1.1 Hardware

Level	Designation	
	Generic	Specific
1.1.1 System 1.1.2 Subsystem 1.1.3 Assembly-component 1.1.4 Subassembly-subcomponent 1.1.5 Part		

1.2 Functional

Characteristic	Designation	
	Generic	Specific
1.2.1 Mission 1.2.2 Phase 1.2.3 Phase segment 1.2.4 Maneuver-assignment 1.2.5 Function		

2. Reference Data

2.1 Title
2.2 Author
2.3 Source
2.4 Security Class
2.5 Location (in Data Store)
2.6 Edition
2.7 Generator
2.8 Developmental Phase
2.9 Entry Data
Document Name
Associated Entries
Date Generated

3. Type of Human Factors Data

Area	Form		Source						Type			
	Technique	Results	Review	Analysis	Simulation	Experimentation	Evaluation	Testing	Design Requirement	Schedule Requirement	Capability	Constraint
3.1 Anthropometry												
3.2 Environmental Parameters												
3.3 Life Support												
3.4 Logistics												
3.5 Maintenance Design												
3.6 Operational Design												
3.7 Performance Aids												
3.8 Personal Equipment												
3.9 Personnel												
3.10 Proficiency Measurement												
3.11 Task and Performance Description												
3.11.1 Task												
3.11.2 Performance												
3.12 Training												
3.13 Training Equipment and Aids												
3.14 Workplace Layout												

Figure 3. Classification form.

Table X

Classification Categories

Training

- Training Objectives
  - General objectives
  - Specific objectives
    - Operations
    - Duties
    - Tasks
    - Skills
    - Knowledges
    - Attitudes
- Trainee Personnel
  - Job specialty code
  - Job specialty description
- Teaching Personnel
  - Job specialty code
  - Job specialty description
- Selection Constraints
  - Aptitudes
    - Physical
      - Coordination
      - Visual
      - Auditory
      - Bodily requirements
    - Mental
      - I.Q.
      - Mathematics
      - Mechanical
      - Clerical
      - Electronics
    - Social
      - Aggressiveness
      - Fluency of speech
      - Social poise
    - Emotional
      - Stability
      - Personality Test Scores
  - Pre-requisite training requirements
    - Introductory training schools
    - Specialized training schools
    - Introductory training courses
    - Specialized training courses
  - Skill requirements
  - Experience
    - Type
    - Time
- Job Task Analysis (JTA)
- Curriculum Development
  - Knowledge requirements
  - Skill requirements
  - Construction of the training program
    - Programming of instruction
    - Practice materials
- Personnel Evaluation
  - Criterion of proficiency
  - Tests
    - Achievement
    - Job proficiency
- Training Equipment and Aids
  - Trainers
    - Simulator
    - Training device
    - Training aid
    - Training attachment
  - Training accessory
  - Training part
- Learning Facilitating Features
  - Transfer of training
  - Programming
  - Feedback
    - Instructor provided
    - Trainee provided
    - Automatic
    - Supervisor provided
  - Task completion
    - Provided
    - Indicated
  - Information distribution
  - Motivation
- Facilities Required
  - Description
  - Environmental parameters
- Equipment
- Training Time
  - Total training
  - Weekly
  - Daily
- Administrative Requirements
  - Personnel
  - Equipment
  - Supplies
- Cost
  - Facilities
  - Teacher Personnel
  - Trainee Personnel
  - Equipment
  - Supplies
  - Training Equipment and Aids
- Types of Training
  - Location
    - Factory
    - ATC resident
    - Unit
    - Mobile
    - On-the-Job (OJT)
    - Field
    - Area
  - Subject matter
    - Military
    - Technical
    - Special
  - Personnel
    - Recruit
    - General Line
    - Military Assistance

Relationships Among Human Factors Areas

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 Anthropometry														
2 Environmental Parameters														
3 Life Support														
4 Logistics														
5 Maintenance Design														
6 Operational Design														
7 Performance Aids														
8 Personal Equipment														
9 Personnel														
10 Proficiency Measurement														
11 Task and Performance Description														
12 Training														
13 Training Equipment and Aids														
14 Workplace Layout														

a. Entry above diagonal indicates column variable was independent, row variable dependent.

b. Entry below diagonal indicates column variable was dependent, row variable independent.

c. Entry in analogous cells both above and below diagonal indicates no cause-effect relationship or relationship in both directions.

Figure 4. Interactions form.

SECTION VI

AUTOMATED HUMAN FACTORS TASK DATA HANDLING

The last six questionnaire items (cf. Appendix III) yielded information related to current and potential uses of computers in the handling of human factors data. These data and related information gathered during the interviews provided a basis for recommending characteristics of an automated human factors data handling system which were perceived by the respondents and the interviewees as necessary and/or desirable.

Current Computer Uses and Human Factors Task Data Retrieval Time

The current and potential computer uses as indicated by the respondents to the questionnaire are presented in Table XI and XII. It was somewhat surprising to find that only 25 per cent of the responses indicated that no use was currently being made of computers. However, it is probably safe to assume also that no use was being made of computers by respondents who did not respond to this item. A generally felt need, however, was reflected in the respondents' nearly universal agreement (about 80 per cent of the total number of responses) that some use could be made of computers in their work.

Although non-managerial personnel currently make relatively little use of computers, about 75 per cent of their responses indicated that they thought some use could be made of computers in their work, especially in performing literature searching functions.

In Table XIII it can be seen that data retrieval time was undoubtedly perceived by the respondents as important: 79 per cent of the total group responded affirmatively to this item, and there was no Personnel Group for whom data retrieval time was unimportant.

In Table XIV is presented a comparison of the current and desired data retrieval times reported by the respondents. Since modal responses in both cases lay in the range of one to six days, the initial inclination might be to interpret these results as indicative that about 30 per cent of the respondents were satisfied with their current data retrieval times. It is impossible to determine from the data in Table XIV, however, whether the 30 per cent of the respondents whose current data retrieval time is one to six days, are the same 30 per cent of the respondents whose desired data retrieval time is one to six days. In order to ascertain the extent of the respondents' satisfaction with current data retrieval times, a further tabulation--one which compared current and desired data retrieval times for each respondent--was necessary. The results of this tabulation are summarized in Table XV, which shows that 46 per cent of the respondents indicated as desirable, retrieval times less than their

Table XI

Current Uses of Computers

Response Category		Personnel Group	Program Level Managers X	Program Level Managers %	Personnel Subsystem Managers X	Personnel Subsystem Managers %	Department Heads X	Department Heads %	Non-managerial Personnel X	Non-managerial Personnel %	Total X	Total %
Storage and Retrieval	Literature Search	Bibliography	3	14			1	3	1	4	5	5
		Abstracts of Reports	2	10			1	3	1	4	4	4
		Original	1	5							1	1
	Raw Data	System Specific Personnel Subsystem	1	5	2	9	2	7			5	5
		System Specific Hardware			3	14	2	7			5	5
		Human Engineering Including Maintainability	1	5			2	7	1	4	4	4
		Hardware Inventory	1	5			1	3	1	4	3	3
		Personnel Inventory							1	4	1	1
		Task/Performance	1	5							1	1
		General Data Bank			1	5					1	1
Processing	Simulation for	Human Performance Estimate	1	5	1	5	2	7			4	4
		Equipment Performance Estimate	1	5			1	3	1	4	3	3
		General Simulation			1	5	2	7			3	3
		Management Tool	2	10							2	2
		Manning Estimate					2	7			2	2
		Cost Estimate	1	5							1	1
		Hardware Requirement Estimate					1	3			1	1
	Other Process	General Processing	4	9	1	5	2	7			7	7
		Statistical Analysis			1	5	4	14			5	5
		Generate Random Series			1	5					1	1
		Integrate/Combine							1	4	1	1
		No Use	2	10	5	23	6	21	11	46	24	25
		No Response			6	27			6	25	12	13
		Total	21		22		29		24		96	

Table XII

Potential Uses of Computers

Response Category		Personnel Group	Program Level Managers X	Program Level Managers %	Personnel Subsystems Managers X	Personnel Subsystems Managers %	Department Heads X	Department Heads %	Non-managerial Personnel X	Non-managerial Personnel %	Total X	Total %
Storage and Retrieval	Literature Search	Bibliography	2	15	1	3			4	15	7	7
		Abstracts of Reports	1	8					3	12	4	4
		Original	1	8	1	3			1	4	3	3
	Raw Data	Personnel Inventory	1	8			3	10	3	12	7	7
		Task/Performance	1	8	3	10	2	7	1	4	7	7
		Human Engineering Including Maintenance	1	8	1	3	2	7			4	4
		System Specific Hardware	1	8	3	10					4	4
		Hardware Inventory	1	8			2	7			3	3
		Training/Testing	1	8	1	3			1	4	3	3
		System Specific Personnel Subsystem			3	10					3	3
		Anthropometry			2	7					2	2
	Other	General Data Bank			1	3			1	4	2	2
		Miscelaneous Reply Queries			1	3					1	1
Processing	Simulate for	Equipment Performance Estimate			3	10	2	7			5	5
		Human Performance Estimate					5	16			5	5
		Manning Estimate					2	7	2	8	4	4
		Hardware Requirement Estimate					3	10	1	4	4	4
		General Simulation			2	7	1	3			3	3
		Reliability Estimate			1	3	1	3			2	2
		Cost Estimate							1	4	1	1
		Maintenance Estimate			1	3					1	1
	Other Process	Statistical Analysis			2	7	1	3			3	3
		Task Analysis					2	7	1	4	3	3
		Integration/Combination					2	7			2	2
		General Processing							1	4	1	1
		Update a Bank			1	3					1	1
		Current is Adequate	3	23	1	3	2	7	3	12	9	9
		No Response			3	10			2	8	5	5
		No Use					1	3	1	4	2	2
		Total	13		31		31		26		101	

Table XIII

Importance of Data Retrieval Time

Response Category \ Personnel Group	Program Level Managers		Personnel Sybsystem Managers		Department Heads		Non-managerial Personnel		Total	
	X	%	X	%	X	%	X	%	X	%
Extremely Important			3	19	2	11			5	8
Important	7	78	8	50	15	79	18	78	48	72
Unimportant	1	11	3	19	1	5			5	6
No Response	1	11	2	13	1	5	5	22	9	13
Total	9		16		19		23		67	

Table XIV

Current and Desired Data Retrieval Times

Response Category	Personnel Group	Program Level Managers X	Program Level Managers %	Personnel Subsystem Managers X	Personnel Subsystem Managers %	Department Heads X	Department Heads %	Non-managerial Personnel X	Non-managerial Personnel %	Total X	Total %
Current	<One day			2	13	2	11	4	17	8	12
	One to six days	5	56	5	31	10	53	3	13	23	34
	One week to < 1 month	2	22	3	19	3	16	4	17	12	18
	One month to < 3 months					1	5	3	13	4	6
	>Three months							1	4	1	2
	No Response	2	22	6	38	3	16	8	35	19	28
	Total Responses	9		16		19		23		67	
Desired	<One day	1	11	6	38	5	26	5	22	17	25
	One to 6 days	5	56	4	25	7	37	5	22	21	31
	One week to <1 month	1	11	1	6	3	16	5	22	10	15
	>One month							1	4	1	2
	Variable					1	5	1	4	2	3
	No Response	2	22	5	31	3	16	6	26	16	24
	Total Responses	9		16		19		23		67	

Table XV

Relation of Current and Desired
Data Retrieval Times

Response Category \ Personnel Group	Program Level Managers		Personnel Subsystem Managers		Department Heads		Non-managerial Personnel		Total	
	X	%	X	%	X	%	X	%	X	%
Current > Desirable	2	22	8	50	11	58	10	44	31	46
Current ≤ Desirable	5	56	4	25	7	37	8	35	24	36
No Response	2	22	4	25	1	5	5	22	12	18
Total	9		16		19		23		67	

current retrieval times. Thirty-six per cent of the respondents, on the other hand, were clearly satisfied with current data retrieval times, as indicated by responses in which current data retrieval times were less than or equal to desirable ones. It is difficult to determine the degree of satisfaction of the 18 per cent of the group who did not respond. It is probably safe to assume that subjects who failed to respond to these items were, at any rate, not dissatisfied with current data retrieval time. For these respondents, current data retrieval times may either have been satisfactory or of no concern. It is probable that the group for whom current data retrieval times were satisfactory was heavily populated with respondents from installations where computers were in common use.

There was little agreement with regard to the anticipated frequency of use of the desired response times. In Table XVI it can be seen that the range of responses to this question varied from several times per day to less than once per month. Very few of the responses indicated that the desired response times would be used more frequently than twice per month. A more accurate prediction of the frequency of use of rapid response times would, of course, require consideration of the number of human factors researchers in any given organization.

Thirty-three per cent of the respondents, primarily those to whom response time was unimportant or who failed to answer the question regarding importance, failed to respond to this item.

Summarily then, the following conclusions may be derived from the computer-related questionnaire items: (1) about 80 per cent of the respondents feel that some use could be made of computers in their work, (2) data retrieval time is important to at least 80 per cent of the respondents, (3) current modal data retrieval times are from one to six days, (4) about half of the respondents, probably those who do not have ready access to computers, are dissatisfied with current data retrieval times, (5) data retrieval times of less than one day would probably not be used more than twice a month by each respondent.

Recommendations for an Automated Human Factors Data Handling System

Since the information obtained during the interviews and which related to automated human factors data handling was not amenable to tabular presentation or quantification, it was integrated into, and presented as it either served to substantiate or refute, the recommendations which follow.

In order maximally to facilitate system operation, a computerized human factors data retrieval system must be capable of performing the following functions:

1. Supply data, including task analyses and manning and training requirements, for any part of a system which has been duplicated in past systems or on an experimental basis.

Table XVI

Anticipated Frequency of Use of Desired Response Time

Response Category \ Personnel Group	Program Level Managers		Personnel Subsystem Managers		Department Heads		Non-managerial Personnel		Total	
	X	%	X	%	X	%	X	%	X	%
Continuously			1	6	2	11	2	9	5	8
>Once/day	1	11	1	6	2	11			4	6
Once/day			1	6			1	4	2	3
Once/2 days	1	11			1	5			2	3
Once/1/2 week							1	4	1	2
Once/week	1	11			2	11			3	5
Twice/month	1	11	2	13	1	5	3	13	7	10
Once/month			3	19	2	11	1	4	6	9
<Once/month			1	6	4	21	1	4	6	9
"Infrequently"	2	22					1	4	3	5
"< 50% of the time"							1	4	1	2
">50% of the time"					1	5	4	17	5	8
No Response	3	33	7	44	4	21	8	35	22	33
Total	9		16		19		23		67	

Implicit in this recommendation and to a lesser degree some of those which follow, is a centrally maintained data store. Although there was nearly universal agreement among the interviewees on the desirability of such a pool, some reservations were expressed.

The individual contractors were obviously cognizant of the necessity of the rapid retrieval of data generated in the development of past systems for the successful fulfillment of contract requirements and for the maintenance of their own competitive positions. When questioned with regard to their primary data sources, representatives for Contractor 9 were able immediately to cite no less than five separate, internally maintained data sources. It appeared further that these contractors would be reluctant to contribute data to a general pool, as reflected in statements of representatives of Contractor 2, who felt that to release "hard-got" data, considered proprietary by both contractors and government, to a general pool would be detrimental to their competitive position. They could, nevertheless, see the value of a readily available store of working tools; e.g., programs, subroutines, experimental designs and methods. Such reservations are clearly gratuitous in light of current computer methodology, which is sufficiently sophisticated to permit the selective release of classified or proprietary information to authorized personnel.

Representatives from Government Agency 3 indicated, that "as much information as possible is needed from previous manned flights," and that the anticipated difficulty (due primarily to competitive considerations) in obtaining this information would undoubtedly act as a significant deterrent to optimal system development. Partially as the result of the perceived unavailability of these necessary data, personnel of Government Agency 3 were performing task analyses in order to solve their own specific design and performance problems. In so doing, considerable duplication of the efforts of previous contractors was undoubtedly involved. Furthermore, there was no standard format for reporting the results that were obtained. A question naturally arises as to the effects of these deficiencies upon the ultimate fate of the task analysis data which Government Agency 3 is now generating. Since many of the experiments in which these data were generated were not specifically required by contract, it is highly improbable that the data will be available for the solution of related design and performance problems by future contractors. On the other hand, reports of studies done for another project by the same government agency were all reported quarterly to the System Program Office, whether or not the data generated had any direct bearing on actual system development. While it is difficult to establish a "happy medium" between these two extremes, it appears that the one at which an inordinate amount of data are stored and made available for retrieval is to be preferred to the storage of an insufficient amount of data.

The storage and rapid retrieval of task analysis data would also serve to facilitate the solution of certain methodological problems now encountered. For example, representatives of Contractor 8 expressed considerable concern with regard to deciding which tasks warranted analyses.

They described their present approach as a "shotgun" one, in which a subjective evaluation was first made of the areas in which time stress and errors appeared most likely, and this evaluation confirmed, or infirmed by the performance of task analyses. Such an approach appeared somewhat less than optimal and could probably be improved or replaced by one in which, on the basis of data generated by a great number of task analyses performed in the past, one could more objectively ascertain which areas were indeed most subject to the effects of errors and time stress. Such an approach would hopefully lead to the performance of an ever-diminishing number of task analyses by each successive contractor. This in turn would release more of the contractors' time and funds for more detailed analyses of new tasks as they are created, and for application to other critical aspects of system development.

2. Indicate rapidly and at any time during the system life cycle the availability of the facilities, training aids, aerospace ground equipment, and trained personnel necessary to design, develop, operate and maintain the system.

The necessity of rapid access to these data appeared proportional to the number and size of the contracting agencies upon whom operating of the system depends; i.e., although relatively large contracting agencies were usually better equipped to cope with usual system development problems than were smaller contractors, the increased division of labor which accompanied corporate growth resulted also in an increased likelihood of duplication of effort and critical oversights. That these were compounded by situations in which more than one contractor was responsible for system operation was reflected in the following statement from a representative of Contractor 8:

> The interface of the contractors at the launch complex is quite error prone because there has been no central management in facility design.

Also operating at odds with the necessity for rapid access to personnel and equipment data was the usual physical separation of human factors data generators, design engineers, and technical writers. This often produced a situation in which there was considerable delay from the time when useful data were generated to the time when they became available for direct application to system design. Many contractors had taken steps to decrease this delay by selectively employing psychologists with engineering experience and/or engineers with experience in human psychology. However, a distinct separation of these data generators and users from the writers of technical publications persisted in all the contracting agencies visited.

Considerable disagreement existed with regard to the time in the system life cycle when human factors considerations are most important. Human factors personnel at Contractor 5 were unanimous in agreeing that the design phase was the only time for human factors considerations. This point of view was substantiated by what was referred to as, "incidents following both inclusion and exclusion of such requirements." At the other extreme were representatives from Contractor 8, who expressed the opinion that the primary consideration of human factors should occur in maintenance, inspection, launching, and safety, and that designers should not be required to "waste time" waiting for task and function analyses. Contractor 8 included human factors personnel on all design and production teams.

3. Simulate any proposed system or portion thereof at any time during the system life cycle and at various levels of detail.

The verity of the need for these functions was readily apparent, since several of the contractors reported that such computer functions were already being performed in their organizations at the time of the interview. Impetus has been lent this trend by well defined AF contract requirements for simulation, especially for training purposes. The importance of product simulation as a tool for facilitating the design and development of training devices was stressed by representatives of Contractor 2, who reported that their organization always relied heavily on computerized product simulators, irrespective of contract requirements. Similarly, representatives of Contractor 3 reported that, owing to computer simulation early in one of their primary programs, design changes were made which under any other circumstances, would have been impossible. The importance of computer simulation as perceived by private contractors was perhaps made most clear by the representatives from Contractor 5: although their organization had access to modern electronic data storage and processing equipment, the only use to which the computer was put other than in the performance of statistical routines was in simulation of various system parts or subsystems.

Simulation may also provide the only means for reliability estimation in systems which cannot be made actually to "go" except in times of national emergency; for example, Contractor 4 was developing a mathematical model for simulating the performance of an ICBM system.

Computer simulation during the conceptual and planning phases of system development would undoubtedly facilitate the objective and accurate estimation of costs, evaluations of trade-offs, alternative solutions, and developmental steps.

4. Be amenable to frequent updating.

It is obvious that, were a computer storage system not capable of frequent updating, its use would be as limited as that of a handbook (probably even more so, since the retrieval of data from handbooks is generally easier than is the retrieval of data from computer storage). Indeed, it is probably safe to assume that the principal value of any data bank derives from the recency of its entries.

Several contractors (6, 8, 9) were, at the time of the interviews, performing a computerized data communication service for their researchers. A record was kept of the major fields of interest and the nature of the ongoing research of the employees and notices of new accessions, immediately upon receipt, sent them. Such a service was viewed by the researchers as necessary and invaluable.

5. Provide summaries of basic data likely to be required in developing a particular system and based on early planning specifications regarding the nature of the final products.

This recommendation is closely related to (4) above, in that the recency of entries and outputs will determine the ultimate utility of the system.

A recent study (8) demonstrated that dissatisfaction with current human factors reference works was nearly universal. Forty-nine of 211 suggestions for improving human factors handbooks indicated the desire of the respondents for more basic quantitative data, more references, and less "expertising." Another 40 of the suggestions were for more frequent updating. Any proposed automatic data retrieval system should at least provide effective means for allaying these two objections.

Representatives of at least two contractors expressed some doubt with regard to the usefulness of handbook-type data summaries, their extensive reliance on such sources notwithstanding. Contractor 9 was using its own library system which provided for print-outs of machine abstracts of stored research reports on McBee cards. In light of the availability of this and similar services (e.g., Tufts, DDC), representatives from Contractor 9 were somewhat skeptical of the need for a "fact retrieval" system, especially on grounds of its probable high cost as compared to the probable increase in data availability over and above that which was already being provided by their own and related automated library systems. The objection of representatives from Contractor 3 was more general and can probably be summarily dismissed: "Since handbooks do not deal with 'big pictures,' they cannot tell a practicing human factors man what he needs to know."

6. In the event that special situations should arise which require data which are unavailable in handbooks, or when latest updated data are required, the computer system should generate replies to specific queries. (While it is not suggested that this be the normal mode of operation, the option should be available.)

This feature would be especially valuable as an interpolating device, and could perhaps even eliminate the need for certain routine, non-critical experiments. Representatives from Government Agency 1 reported that such functions were being performed by "specialists" in their organization, and that <u>no</u> experiments were performed to solve human factors problems in system design. Since specialists undoubtedly possess varying degrees of expertise, the purposes of system development and design would probably be well served by the standardization of interpolative methodology. For example, the amount of torque required to turn a two-inch knob may or may not lie midway between the amounts required to turn one- and three-inch knobs, all other things being equal. A machine-generated curve which was based on relatively few data points and which described torque as a function of knob diameter would probably permit more accurate between-data-point interpolation than would reliance on varying degrees of expertise.

In addition to this proposed interpolative function, Government Agency 2 has used an "in-commission rate" model to help solve the following problems: estimation of the effects of changes in technical orders, trade-offs between availability of resources, maintenance demands, and unit manning; between checkout frequency, failure rates, and maintenance work hours; and for determining the extent of wear added to the system by unscheduled maintenance checkouts. Contractor 4 was using a computer to project and update continuously an estimate of human reliability in system operation.

This ability of the system to aid in the solution of system-specific problems is viewed as especially important, as it appears that these are the problems for which solutions will not previously have been generated.

7. Throughout development, the system should produce automatically and as needed those system-specific documents identifiable today as, for example, QQPRI, and TEPI.

Considerable concern was expressed by almost all of the Contracting and Government Agencies over whether or not the effort required to produce these documents was warranted by their ultimate value. Three inadequacies were frequently cited by the interviewees: (1) the immediate applicability of these documents was limited and sometimes obviated by their production late in the system life cycle; (2) much relevant information was omitted; and (3) relevant information was often obscured by irrelevant verbiage. In addition, representatives from Contractor 6 were much concerned about "wasted effort" in the preparation of Personnel Subsystem documents, and cited a case in which their entire human factors section had been called upon to prepare a section on operator tasks which was discarded from a subsequent revision of the QQPRI document. Representatives from Contractor 2 maintained that, "if the broadest interpretation of the Personnel Equipment Data specifications were followed, an intolerable burden would be imposed on the system."

While these inadequacies may have been due in large measure to failure of the contractors to follow recommended procedures and regulations for fulfilling contract requirements, it does not necessarily follow that the situation would be improved by strict adherence to the recommended procedures. Indeed, quite the opposite may be the case; near-unanimous failure to comply with regulations may be indicative of shortcomings in the regulations themselves.

The difficulties stem at least in part from the imprecise nature of the regulations and specifications governing the preparation of personnel subsystem documents. There is room for considerable latitude in interpreting these documents. Increased rigidity of the regulations and specifications, however, is not necessarily the answer, since this may prove even less conducive to efficient system operation than is the situation as it now exists. It is, therefore, suggested that the requirements for personnel subsystem data are sufficient as they stand, but that it would be in the best interests of both contractors and their respective procuring activities to standardize the form in which these data are reported. While (3) represents a step in this direction, it is hoped that the classification system proposed herein will provide a more orderly means for data organization and that the many possible recombinations of stored entries will provide for the generation of personnel subsystem documents which conform to present regulations and future amendments or modifications thereof.

SECTION VII

IMPLEMENTATION

In the preceding sections characteristics of an automated human factors data handling system were proposed, and the need for the development of a standard classification scheme based on the structure of human factors data was demonstrated. The following section presents suggestions and priorities for implementing the foregoing recommendations.

A human factors data handling system that fulfills the requirements described cannot be designed and presented to system developers as an operable system. Rather, it must be designed in a way such that use of the data system and an acquisition of the software and hardware will permit an orderly progression from current to newly developed methods. It has been established that some human factors data handling functions are now accomplished by the use of computers at some installations. To the extent that current automated systems fulfill the requirements set forth in the preceding section, currently used methods can serve as the point of departure for the design of a more sophisticated data system. Provision must be made for test and evaluation of a newly designed system as it is developed and used.

The first steps should be the expansion of lists of classifying terms within the framework suggested and presented in Section V, Data Classification. This should be done by, or in consultation with, experts and current practitioners in each of the various fields. Classifiers used at the outset need not be considered as immodifiable or unexpandable, since appropriate programming will hopefully refine the classifier list automatically under constant and frequent use. The initial classifiers should, in any event, reflect the true structure of human factors data to facilitate access to, and storage of, the data for all users and generators.

The second step should be the development of programs to store each of the various kind of human factors data and to provide for classification of the stored data at each of the levels described.

The third step should be the selection of a system to which the designed data handling system can be applied. The following criteria should govern the selection of the system:

- It should be in a very early stage.
- It should be modest in size or have a subsystem which can be treated separately by the data handling system.

- During the course of development, it should be possible to use the newly designed data handling system concurrently with normally used data handling systems.

- It must be possible to compare accuracy, speed, and cost of operation of the newly designed data handling system to those of the normally used system.

- The system should be typical of Air Force or NASA systems.

- The anticipated development time should be as short as possible.

The fourth step should be actual operation of the designed data handling system in the test system under development. In the course of the test system development, all human factors data should be stored and handled to accomplish the recommended goals and to the fullest possible extent in a limited system. In addition any data from sources external to the test system but used in its development should also be stored in the data handling system.

The fifth step should be application of the data handling system to still another system under development and selected according to the same criteria. Development of the first system selected need not be complete. Application of the data handling system to the second test system will be exactly the same as for the first, with one important exception for the second system a store of data will be available at the start.

At this point evaluation of the methods will indicate utility of the newly designed human factors data handling system within a system and, to some extent, across systems. Projection of results to larger and more complex systems will provide criteria and direction for development and general application of the newly designed data handling system.

The design and implementation of the data handling system should be directed toward accomplishing the functions described in the preceding section. When concurrent development of all functions is impossible, decisions as to which to select should be based on the effort which will produce the greatest payoff in terms of facilitating test system development. The priority for selection from among the recommended functions should be as follows, with the first mentioned having the highest priority.

1. Throughout development, the system should produce automatically and as needed those system-specific documents identifiable today as, for example, QQPRI, and TEPI.

2. In the event that special situations should arise which require data which are unavailable in handbooks, or when latest updated data are required, the computer system should generate replies to specific queries. (While it is not suggested that this be the normal mode of operation, the option should be available.)

3. Provide summaries of basic data likely to be required in developing a particular system and based on early planning specifications regarding the nature of the final products.

4. Be amenable to frequent updating.

5. Simulate any proposed system or portion thereof at any time during the system life cycle and at various levels of detail.

6. Indicate rapidly and at any time during the system life cycle the availability of the facilities, training aids, aerospace ground equipment, and trained personnel necessary to design, develop, operate and maintain the system.

7. Supply data, including task analyses and manning and training requirements, for any part of a system which has been duplicated in past systems or on an experimental basis.

APPENDIX I

LITERATURE REVIEW

The documents deemed relevant to the purposes of the investigation were of two kinds. One class was comprised of Air Force manuals (3 and 1), which served the dual purpose of familiarizing the investigators prior to the interviews with the extent of the limitations placed upon current human factors efforts by contractors, and of providing a description of human factors data as formally defined by procuring activities.

The second class of literature was comprised primarily of handbooks which provide summaries of the results of human factors research; (7, 4, 6, and 5). Also included in this class were textbooks and other documents which served to indicate the nature of current practice in indexing and classifying human factors data.

The examination of the literature resulted in three important contributions to this study:

1. The government documents provided information about the content of reports and documents required in system development by current regulations and established procedures. In addition, information was provided which helped to indicate the sources of the information in such documents and to identify the users for whom the documents are prepared.

2. Handbooks and other source books helped to identify areas of interest for those persons who have the responsibility for generating the documents described in (1) above.

3. The study of tables of contents and indexes provided insights into the methods of classification of currently used human factors data and provided the base for the suggested classification system reported in the final section of this report.

A complete list of the documents reviewed for this part of the study can be found in Bibliography.

APPENDIX II

INTERVIEW PROCEDURE

Seventy-three persons who were involved in system design, development, and operation were interviewed. Of these, two were contractor managers of a complete development program, six were managers of the personnel subsystems section of their respective organization, 17 were heads of development for a specific personnel subsystem department, and the remaining 48 were non-managerial personnel.

Interviews were held in 12 offices which were engaged in system development, and included offices of major contractors, system project offices, Air Force Commands, and the NASA Manned Spacecraft Center. The interviews were focused on nine major systems which were selected as representative of various manufacturers, AF and NASA divisions, phases of system development, and types of weapon system (manned vs. unmanned, ground vs. airborne, etc.). The criteria for the selection of the system which were examined were:

1. The systems selected were sufficiently broad in scope to include many different kinds of human factors data. While the purpose of the study was not the accumulation of a data bank, it was intended that the classification scheme developed would provide a framework within which such a bank could evolve.

2. The systems selected for study were representative of most kinds of aerospace developments, so that the resulting techniques would be generally useful to all potential users.

3. The systems were selected to be as representative as possible of the contractors who work on AF and NASA systems.

4. Systems were selected which could be studied with a minimum of restrictions imposed by security or proprietary considerations.

5. Systems were selected which could be studied in depth and within the contractual constraints of available personnel and time.

6. The systems selected for study included samples at different stages of development so that the schemes developed would not be biased toward a particular phase.

Introductory letters, designed to acquaint them with the overall nature of the research program, were sent to prospective interviewees. These were followed by telephone calls, the purpose of which was to answer any questions which the prospective interviewees might have had and to establish definite times and dates for the interviews.

The discussions held during the interviews centered around a list of questions which was compiled by the investigators prior to the visit. These were designed to elicit specific responses which would be relevant to the purposes of the investigation.

The interviews varied from one-half to four hours, depending primarily on the length of the time which the interviewees were willing to spend. The total lengths of the on-site visits varied from one-half to two days.

Immediately upon returning from each interview, a trip report was written, based on notes taken on the events which had transpired and the comments which had been made by the interviewees. These trip reports and the notes upon which they were based were retained and served as the principal sources for the analysis of the interview data.

The introductory letter and the list of questions are attached, respectively, as Appendixes V and VI. These were modified as applicable to the installations visited.

APPENDIX III

QUESTIONNAIRE

Name Position (Job title) Job title of four closest working associates
Professional journals and technical publications most frequently read. (Not necessarily as sources of data in performing job)
Professional organizations of which you are a member. Also list those for which you have prepared and/or delivered papers or attended meetings.
What are the most important data sources and inputs with which you work. (List handbooks used frequently, frequency of use of research reports, outputs of other human factors specialists e.g., maintainability analysis, QQPRI, etc., sources of documentation referred to, and others which you consider important).

Forms of processing (What do you do with raw inputs that transforms them into a new useable product. List as many as you can in order of importance in your job. Example: Review engineering drawings for compliance with regs. specifying human factors requirements. Or; Generate task data based on observation of performance with hardware.)

Forms of outputs (Specific examples of your contribution to system development associate each example with system and phase of development.)

Form of output	System	Phase
(Examples)		
Revised task analyses	Titan II	Cat. II Testing
Narative report re design recommendations	F-111	Design

What uses do you make of computers in either retrieval, processing, or storing of data?
In what ways do you think computers could be used in making your job easier, faster, or more efficient in some way?
Is response time (in request for data) important to you? What response times do you work with now? What kind of response time would you like to have available? How often would you use the most rapid response time you mentioned?

APPENDIX IV

ANALYSIS

Analysis of Data Gathering Results

Results from the literature surveys, interviews, and questionnaires were extensively summarized in narrative and, where feasible, frequency table form. Results across all of these techniques were then consolidated into categories having differential implications for design of an automated human task data handling system.

Results from the literature survey were used as the primary source for defining the kinds of subsystem data with which the automated system would have to deal, and were also basic to defining sources, generators, users, developmental phase relationships, and levels of detail for each kind of data. In addition, results from the literature survey were used selectively to supplement, clarify, and justify conclusions and recommendations throughout the report.

Analysis of interview results consisted primarily of direct extraction of written observations and comments from field visits. A systematic review of these results was used both to establish modal response and variations across systems. The comments of interviews were used as a primary source for estimating the impact of human factors data on system development. Historic and status information obtained during field visits was used as a basis for evaluating the effects of different conditions on the nature of human factors efforts in system development. The observations of organizational structures made during field visits, and comments of interviewees were used in identifying the characteristics of human factors generators and users. Comments of interviewees were paramount in deriving suggested functional characteristics for a computerized system to handle human task and related data.

Since the questionnaires involved open-end responses, "Response Categories" were derived for each question on the basis of review of all responses. Responses were then tabulated separately for each different class of system development personnel or "Personnel Group."

Since the comparisons yielded by sorting the questionnaires into Personnel Groups would serve only to indicate the differences between Personnel Groups in the number of responses given to any or all questions, further sorting of the responses was necessary. The questions of primary interest were, "what were the differences between Personnel Groups in the responses to any given question?" and, "what were the differences between responses to any given question irrespective of Personnel Groups?" To these ends, the responses to each item were sorted into Response Categories which, since the questions were of the open-end type, were dictated by the specific content of the responses to each item and were, of necessity, determined on an a posteriori basis.

Since the number of respondents in each Personnel Group was not equal and no restrictions were placed upon the number of responses which each respondent might give to each question, the following percentage score was used to facilitate comparisons across Personnel Groups:

$$S_g = \frac{\Sigma R_g}{\Sigma R_t} \times 100$$

where:

S_g is the percentage score for a given Personnel Group,

ΣR_g is the number of responses made by the given group, and

ΣR_t is the total number of responses made by all groups.

The following percentage score was used to facilitate comparisons across Response Categories (without regard to differences in responses from different Personnel Groups):

$$S_c = \frac{\Sigma R_c}{\Sigma R_g} \times 100$$

where:

S_c is the percentage score for a given Response Category,

ΣR_c is the number of responses in the given category, and

ΣR_g is the total number of responses made to the question.

Questionnaire results were especially useful in describing different types of human factors personnel in terms of their sources of information, areas of contribution, and professional affiliation. They were also useful in describing desired response times of an automated human task data handling system.

APPENDIX V

INTRODUCTORY LETTER FROM INTERVIEWER

IPT INSTITUTE FOR PERFORMANCE TECHNOLOGY
AMERICAN INSTITUTE FOR RESEARCH

18 September 1964

Mr. John A. Smith
JAS Company
Houston, Texas

Dear Mr. Smith:

Computer Concepts, Inc. and the American Institutes for Research are currently engaged in a study aimed toward developing a method of computerization of human factors task data which will make possible the rapid and efficient storage, processing, and retrieval of human factors data used in system development. This project is sponsored jointly by the Air Force and NASA (AF 33(615)-1557, Research on the Use of Computers for Handling Advanced System Human Factors Task Data).

One task assigned under terms of the contract is the study of present methods of handling human factors data in a number of current systems differing in degree of complexity and in phase of development. The magnitude of the [XYZ] effort, the uniqueness of many of the problems which must be solved, and the probable impact of methods developed on Air Force and NASA systems to follow indicate the importance of including [XYZ] in the group of systems which should be studied.

Lewis D. Hannah of the American Institutes of Research, and James Eagle of Computer Concepts, Inc., plan to visit your office 22-23 September as arranged in our telephone conversation 16 September. We will be interested in obtaining the following information:

Lists of documents which establish original requirements and which fix the framework upon which original procedures used in system development were based. Such documents will include statements of work, study plans, Mil Specs and Regs, Exhibits, and others as appropriate to the [XYZ] program. Some of these will be readily available to us. Others we would like to be able to examine or copy while in your office or be directed as to how they might be acquired.

We would then like to learn how the [XYZ] program has implemented procedures to satisfy established requirements with regard to the human factors aspects of system development. Examination of organizational and work flow charts of sections which utilize human factors data will probably be a major source of this information.

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Since formal plans are seldom followed to the letter, we would like to be able to talk with someone who can tell us what informal procedures have been developed to make work efforts more efficient. This will be of special interest when the procedures have to do with the acquisition and/or the generation of human factors data.

We would like to be able to learn the following things about system outputs, either extant or anticipated, such as training manuals, maintenance manuals, operating manuals, and technical handbooks. When in terms of phase of system development were they completed? By what section were they prepared, and what procedures were used in their preparation? By what section and by what procedures were the data necessary for their preparation generated? When in terms of phase of system development were requirements for such outputs fixed in final form?

What procedures have been established for inclusion of human factors considerations in the design of work and living spaces, control, and displays? What are the chief sources of data used in these design efforts?

Then we would like to know what use has been made of computers in any of the above efforts. How has the use of computers aided these efforts and where and for what reasons has the computer not been of material help? What kinds of classification schemes have been used and what kinds of programs and computers have been used in storing and processing data? Here we would like to be able to beg or borrow, examine or copy examples of the input materials and of requests for use of the stored data.

Experience has shown that discussion of such material leads to questions which cannot be anticipated so we would like to have the opportunity to ask such questions to the extent that you can make time available to us.

Very truly yours,

Lewis D. Hannah
Project Director

LDH:vf

APPENDIX VI

SAMPLE OF QUESTIONS ASKED AT THE INTERVIEW

We would like to be able to establish the network of human factors data used in the development of this system. We are interested in identifying:

1. The nature of human factors effort in each phase of system development.

2. The degree of emphasis on human factors through each phase of development.

3. Key points in system development where human factors data have been introduced.

4. What regulations or specifications if any were followed?

5. What requirements were made by the contracting agency for use of human factors specialists on design team?

6. What decisions requiring consideration of human factors data were made by persons not identifiable as human factors specialists?

7. What are chief data sources for each identified decision or input point?

8. What modifications to procedures were made as the system developed?

9. What research had to be done to satisfy needs for data. Was such research done in-house or contracted?

10. What stages in the development cycle provide for redesign of modification following tests of mockups or prototype equipment?

11. What are proposed or existing final products in which human factors considerations are of primary importance?

12. When, in terms of system development, were requirements for these products set and by whom were they set and developed?

13. What documents are available for examination; e.g., proposals, statements of work, progress reports, research reports, manuals prepared, organization charts, regulations, or specifications?

APPENDIX VII

TITLES OF RESPONDENTS TO THE QUESTIONNAIRES

<u>Program Level Managers</u>

Assistant Director, Advanced Plans
Special Assistant to the Director
Chief, Operations Planning Division
Chief, Crew Systems Division
Assistant Chief, Space Mechanics Division
Chief, Crew Integration Branch
Personnel Subsystem Manager, SPO
Supervisory Aerospace Technologist
Supervisory Training Specialist

<u>Personnel Subsystem Managers</u>

Chief of Human Factors
Manager, Command Systems and Human Factors
Head, Human Factors
Manager, Human Factors Department
Director of Research
Manager, Engineering Psychology
Personnel Subsystem Group Leader
Chief, Human Factors Engineering
Manager, Man Machine Engineering Department
Unit Head, Human Factors
Director, Human Factors Technologies
Head, Human Factors Staff
Head, Human Factors Group
Department Manager, Human Factors Department
Advisory Psychologist, Head, Human Factors Group
Supervisor, Human Factors Group

<u>Department Heads</u>

Assistant Chief, Biotechnology Section
Supervisor, Human Factors Analysis Section
Head, Mathematics and Evaluation Studies Department
Principal Scientist
Senior Research Psychologist
Senior Engineering Psychologist
Chief, Maintainability Engineer
Chief, Life Sciences Section
Senior Engineer
Group Head, Display Stems Department
Supervisor, Advance Manned Spacecraft
Personnel Support Section Supervisor
Supervising Psychologist, Human Engineering

Supervisor, Maintainability Engineering
Senior Design Engineer
Manager, Training and Management Personnel
Senior Research Engineer, Lead Engineer
Research Scientist
Manager, Support Systems Engineering

Non-managerial Personnel

Staff Engineer, Aerospace Medicine
Coordinator, Integrated Maintenance Management
Aerospace Technologist
Control Systems Project Engineer
Engineering Psychologist
Specialist Maintainability Engineer
Engineering Psychologist
Psychologist
Human Factors Engineer
Human Factors Engineer
Project Engineering Psychologist
Engineering Psychologist
Engineering Psychologist
Staff Project Engineer
Design Group Engineer
Technical Publications Specialist
Research Engineer, Human Factors
Training Specialist
Design Specialist, Human Factors Engineering
Project Engineer, Human Engineering
Human Factors Scientist
Human Engineer
Associate Project Director

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13. ABSTRACT On the basis of information gathered from generators and users of human factors task data by both interviews and questionnaires and by a review of relevant literature, human factors personnel and data were identified, the relations between them described, and recommendations for an automated human factors task data handling system proposed. Human factors personnel were closely divisible into four hierarchically arranged groups: Program Level Managers, Personnel Subsystem Managers, Department Heads, and Nonmanagerial Personnel. In general, and for the populations described, managers or supervisors were the principal users and nonmanagerial personnel the principal generators of human factors data. A framework that permits classification of both formatted and unformatted data was proposed as responsive to the generally felt need by data generators and users for more orderly "book-keeping" in the human factors realm. Desirable characteristics of an automated human factors task data handling system were derived from the questionnaire responses. The responses also indicated that: (1) about 80% thought some use could be made of computers in their work, (2) retrieval time was important to at least 80%, (3) current modal data retrieval times range from 1 to 6 days, (4) about half of the respondents were dissatisfied with current data retrieval times, (5) retrieval times of less than 1 day would probably not be used more than twice a month by each respondent. Recommendations for implementing the system included steps necessary to design and apply it on a modest scale consonant with current system development.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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Data classification						
Automated data handling						
Personnel subsystems						
Data interrelationships						
Information retrieval						
Interview procedures						
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